CHAPTER 3 - BASIC THEORY

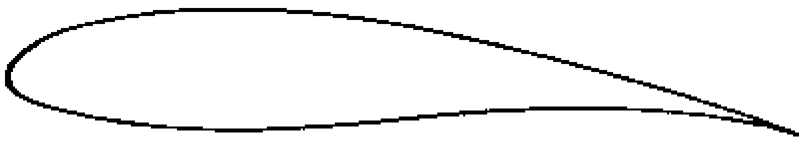
A glider is defined by the FAI as "a fixed-wing aerodyne without a power source".

LIFT

Like all aerodynes, a glider derives its lift from the movement of its wings through the air.

This movement through the air causes the air to flow in a particular pattern around the wings and the wings are shaped in a special way to take advantage of this flow.

The wings of any aircraft, including gliders, are of a cross-sectional shape designed to give the maximum chance of producing lift. This shape, curved or cambered over the top surface and relatively flat underneath, is known as an "aerofoil" section and the exact shape of an aerofoil depends upon what kind of aircraft we wish to apply it to. Gliders, being low speed aircraft with a speed range of 30 to 150 knots, have wings of an aerofoil section which will produce high values of lift at those low speeds without producing too much drag which would retard the machine's progress through the air. Such a wing is usually relatively thick. High-speed aircraft are a different story; their wings are very thin and not at all suited to low-speed flight. When high-speed aircraft need to fly slowly for take-off and landing, they can call upon complex high-lift devices to help them. Such complication is unsuited to gliders, although some research gliders are quite complicated and even a few production gliders in the Open Class are no longer simple.



A typical glider aerofoil section is shown here. Such an aerofoil section meets the requirements for glider design and variations on this basic theme may be considered typical for nearly all glider wings.

A wing produces lift in three different ways.

> Firstly, by its actual shape, which encourages a speeding up of the airflow over the cambered top surface. This in turn results in a lowering of the pressure over the top of the wing (Bernoulli's theory), in effect causing a "suction" upwards. Generally speaking, the thicker the wing and the more pronounced the camber, the more lift will be produced at a given speed.
>
> Secondly, by the actual speed of the wing through the air - the faster the speed, the more lift is produced.
>
> Thirdly, by the angle at which the wing meets the air. This angle, known as the Angle of Attack (AoA), has an important effect on the amount of lift produced by the wing, the lift increasing with an increase in AoA.

The first of these three points, the shape of the aerofoil section, is established by the designer and there is nothing the pilot can do about it except in a very restricted sense if the glider happens to be equipped with flaps. See page 19. Angle of attack and speed are very much under the control of the pilot and a great deal of a glider pilot's training is concerned with a good understanding of keeping both of these factors under control.

The lift developed by an aerofoil section acts at approximately right-angles to the airflow. The point on the wing through which the lift acts is called the Centre of Pressure (CP). The CP moves forward with an increase in AoA and backward with a decrease in AoA.

WEIGHT

The weight of a glider is kept as low as possible consistent with adequate strength. Chapter 7, Basic Airworthiness, covers this in more detail. The lift produced by the wings acts in opposition to the weight of the whole glider. It will therefore be apparent that the lighter the structure and the bigger the wing, the lower will be the resultant rate of sink.

The weight always acts at right angles to the earth's surface, no matter which way the glider is pointing. The point on the glider through which the weight acts is called the Centre of Gravity (CG).

WING LOADING

Wing loading is quite simply the flying weight of the glider divided by the wing area. “Flying weight” is defined as the weight of the glider, plus pilot, parachute, barograph, etc.

The lower the wing-loading, the lower the sink rate and the easier the glider will stay up in weak lift. The higher the wing-loading, the greater the sink rate and the stronger the lift necessary to stay aloft. However, a higher wing loading can sometimes be an advantage for flying fast between thermals, provided the thermals are strong enough to allow the glider to climb in the first place.

Here are some examples of wing-loadings.

Schleicher ASK13 two-seat trainer (flown dual):-

Wing area:	17.5 sq. metres, 188.4 sq. feet
Maximum flying weight:	480 kg, 1058 lbs
Wing-loading:	27.4 kg/sq. m. 5.61 lbs/sq. ft.

Glasflugel H303 Mosquito (including water ballast):-

Wing area:	9.86 sq. metres, 106.1 sq. feet
Maximum flying weight:	450 kg, 990lbs
Wing-loading:	45.6 kg/sq.m.,8.72 lbs/sq. ft.

Lockheed F-104G Starfighter:-

Wing area:	18.22 sq. metres, 196.1 sq. feet
Maximum flying weight:	13054 kg, 28779 lbs
Wing-loading:	716.46 kg/sq.m.,146.75 lbs/sq. ft.

The K13 and the Mosquito, at their wing-loadings, have very moderate sink rates, although the Mosquito (ballasted for fast cross-country flying) will sink somewhat faster than the K13. The Lockheed Starfighter, if its engine stopped, would have the sink rate of a greased housebrick.

DRAG

Profile drag

The shape of a glider offers resistance to its passage through the air. Its actual profile governs the amount of resistance, or drag it produces at any given speed through the air. This so-called "profile drag" is actually a combination of the drag caused by the shape (form drag) and that caused by any roughness of the aircraft skin (skin friction) Form drag is reduced by streamlining - by making the non-lifting parts of the glider (fuselage, etc) of such a shape as to offer the least possible resistance to the air. Skin friction is reduced by keeping the surfaces of the glider as smooth as possible, even to the extent of polishing them in some cases.

Profile drag increases as glider speed increases. However, the picture is worse than you might think. Profile drag actually increases as the square of the speed. Double the speed, four times the drag; three times the speed, nine times the drag, etc. It is obviously in everyone's' interest to make the glider as streamlined as possible and to keep its surface skin smooth and clean. It certainly explains why modern gliders are so slim and their surfaces so highly polished.

Induced drag

There is another source of drag which must be considered. This kind of drag is inseparable from the process of producing lift from the wing and it is proportional to the angle of attack (AoA) of the wing. Because the drag is induced by the lift-producing process, it is naturally known as induced drag.

Generally speaking, in a glider, a high angle of attack means a low speed, unless "G" forces are being produced, a special case which is beyond the scope of this book. Conversely, a low angle of attack means a high speed. Induced drag therefore gets less as the glider's speed increases, the opposite effect to that occurring with profile drag. Induced drag in fact increases as the inverse square of the airspeed - double the speed, a quarter of the induced drag, etc.

Total drag

The total drag of the glider is therefore a combination of profile and induced drags. When glider speed is changing, one kind of drag is increasing while the other is reducing. There is only one speed at which both kinds of drag are at a minimum - the speed is known rather obviously as the Speed for Minimum Drag.

Drag forces act backwards, parallel to the line of the airflow.

Aspect ratio

A glider designer needs to reduce drag to a minimum. Profile drag will be reduced by careful streamlining and attention to the joining of the wing and tail with the fuselage. Induced drag can be reduced by making the glider wings of a particular planform.

At glider speeds, considerable reductions in induced drag can be achieved with wings of long span and narrow chord ("chord" is the distance from leading edge to trailing edge). Such wings are said to have a high **aspect ratio**.

Aspect ratio is simply defined as wing span divided by average wing chord (an average value is needed because most wings are tapered). Examples of glider aspect ratios are just under 10 for a Shortwing Kookaburra (not an aerodynamically efficient glider) to over 28 for a Nimbus 2 (which certainly is efficient). Compare this with 9.4 for the Airbus A320, by airliner standards a known efficient performer.

Winglets

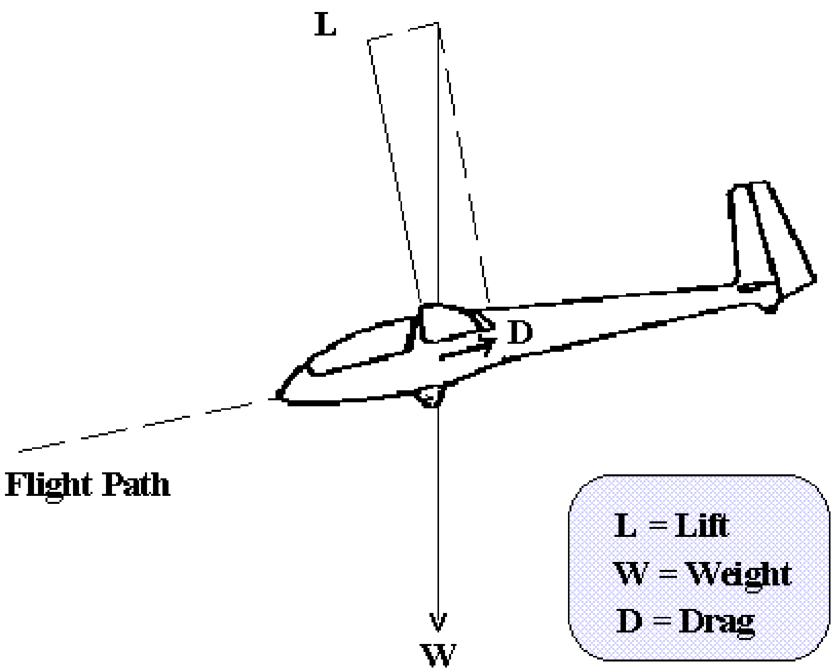
Although a high aspect ratio means low induced drag and very efficient performance, it has a structural penalty. Very long wings of high aspect ratio exert a large bending moment about the wing-root attachments to the fuselage. This can limit the extent to which the designer can (literally) spread his wings.

It has been discovered that a similar effect to increasing aspect ratio, but without quite the same structural penalty, can be achieved by bending the wingtips upwards by varying amounts, in some cases up to 90 degrees. The portion bent upwards, which may be anything up to half a metre in length, is known as a winglet.

Winglet design is by no means simple. Winglets must save more in induced drag than they produce as profile drag. The devices are popular on almost all competitive gliders, so it is assumed they do actually have some benefit. There are also reports that they have a beneficial effect in low-speed handling and reduction of stall speed in some designs.

HOW A GLIDER ACHIEVES FORWARD FLIGHT

Once a glider has been towed aloft by one of the methods of launching described earlier, its only means of propulsion is the force of gravity. From the point of release a glider is constantly losing height in order to maintain forward speed. The more the nose is tilted downward, the more speed is given to the glider, but at the same time the more height is lost in the process. In practice, for the most efficient angle of glide, the nose of the glider is tilted downward by a very small amount, barely noticeable to the onlooker. Modern gliders can achieve very high speeds at very moderate nose-down angles. The diagram which follows illustrates the forces at work around a glider and the resultant "nose down" flight path is a bit exaggerated to show the principle.



From the pilot's point of view, this nose position in relation to the horizon is known as the glider's "attitude". Flying by the attitude of the glider's nose to the horizon is far more important than anything the glider's instruments say.

It is important to realise that, even when a glider is gaining height in free flight, such as soaring in a thermal, it is only doing so because the thermal is ascending at a greater rate than the glider is descending through it. A glider is always descending in free flight and the pilot's job is to find air which is rising at a greater rate than the glider's descent rate.

Minimum sink rate

The higher the wing-loading, the higher will be the rate of sink of the glider. Wing-loadings such as those which appeared earlier in this chapter are typical of the variations seen in the wide variety of glider types produced over the years. At any given wing-loading there is only one speed at which the minimum sink rate will be achieved. This occurs at about 7 knots above the stalling speed at any given weight and is known rather obviously as the Minimum Sink Speed. It is the speed at which the glider should be flown to stay in the air for the longest possible time, not necessarily to achieve the greatest possible distance on a cross-country.

L/D ratio

The ratio between the lift produced by the wing and the drag produced by the whole airframe is critical in a glider. The designer (and the pilot) looks for as much of the former and as little of the latter as possible. Of course there is a compromise and we end up with L/D ratios suited for particular purposes. For example, a competition glider with a very high L/D ratio might be so streamlined that it would be difficult for a large person to fit into its narrow cockpit, whereas a two-seat trainer will be less streamlined because of the need to accommodate two pilots.

A highly streamlined glider with a high aspect ratio will have a high L/D ratio. This means that it loses very little height for much gain in forward distance. In other words, its “glide-angle” is very flat.

The term “glide-angle” can be considered interchangeable with “L/D ratio”. Nowadays a glide angle of 1 in 30 (1 metre height loss for 30 metres of forward gain) would be considered the minimum acceptable value for a single-seater. The very best Open Class gliders are now producing nearly 1 in 60. Note that, for any given glider weight, the maximum achievable L/D ratio occurs at only one speed, which will usually be higher than the speed for minimum sink rate.

GLIDER STABILITY AND CONTROL

Glider stability

These two words “stability” and “control” are very important when talking about any aeroplane, and gliders are no exception. Stability means that the glider must be able to fly for short periods of time without the pilot touching the controls. If it can do this, it means it is a good safe design which will not be too difficult or demanding to fly. Control means the opposite of stability - it means that the glider should be manoeuvrable about all of its three axes of movement (pitch, roll and yaw), using its controls.

If a glider is too stable, it is not very manoeuvrable and is tiring to fly. If it is not stable enough, it is difficult or even dangerous to fly. The designer has to produce a glider with just the right amount of each of these qualities so that it is stable enough to allow us to take our hand off the stick (to unfold a map, for example) without changing our flight path very much, yet still be very manoeuvrable when we want it to be.

The first thing a glider pilot learns when starting training is stability. The instructor will demonstrate that the glider will easily maintain level flight without the pilot's help and even if it is disturbed by turbulence it does not do anything alarming. If the nose moves up or down a bit in rough air, it does so very slowly and the same applies if the glider rolls or yaws a bit. Let us see how it achieves this stability.

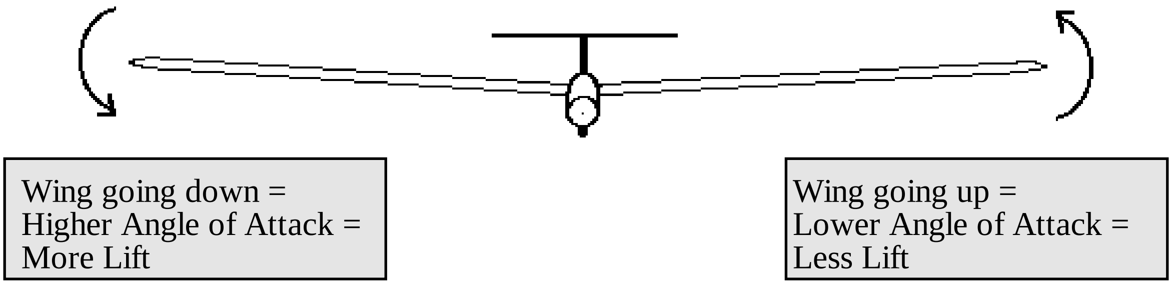
Longitudinal stability or stability in the pitching plane

The tailplane provides pitch stability

The diagram above shows that the tailplane (or horizontal stabilizer) is like a small wing placed at the rear of the glider. This is exactly what it is, and it will produce an upward or downward force to make the nose go back to where the pilot originally put it, if it should get moved from that position for any reason. If the nose tries to go up, the tailplane forces it back down again. If the nose tries to go down, the tailplane makes it go up again. Pitch stability in gliders is provided by the tailplane.

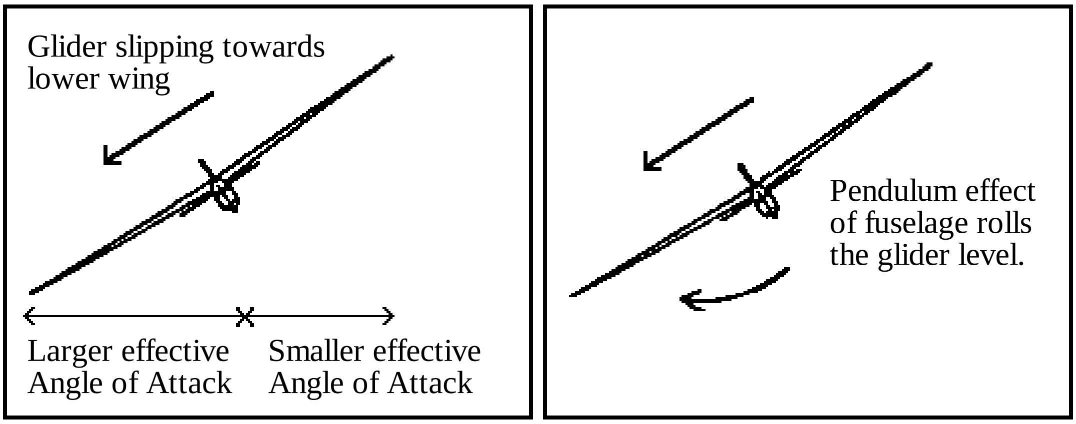
Lateral stability, or stability in roll

Stability in roll, known as lateral stability, is best considered in two parts. The first part is when the glider is actually rolling or banking, either because it has been tipped by a gust or because the pilot has made it roll. When the glider rolls, there is a difference in the amount of lift produced by each wing. The wing going down will produce more lift than the wing coming up, because of the difference in their angles of attack. This tends to damp the rolling of the glider and for this reason is known as **lateral damping.** Lateral damping is a very important factor in roll stability and it is always present as long as the wing is not stalled. If a stall occurs, lateral damping can be lost and this may spell trouble for the unwary pilot.



Lateral damping

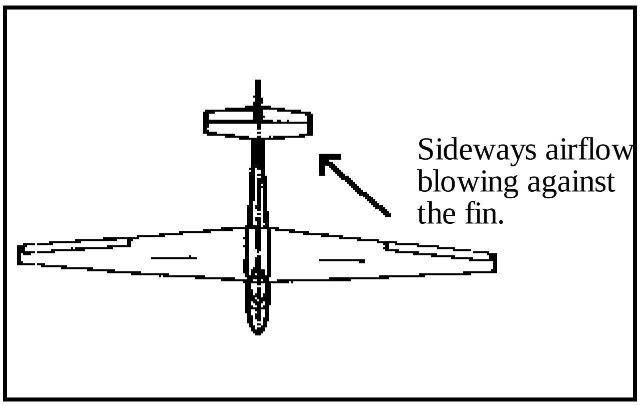
The second part of lateral stability comes into effect when the glider has stopped rolling and is stuck at a particular bank angle. A combination of dihedral effect of the wings and pendulum effect of the fuselage will help restore the glider back to level flight. The diagrams below illustrate both effects.



Dihedral and pendulum effects

Directional stability or stability in yaw

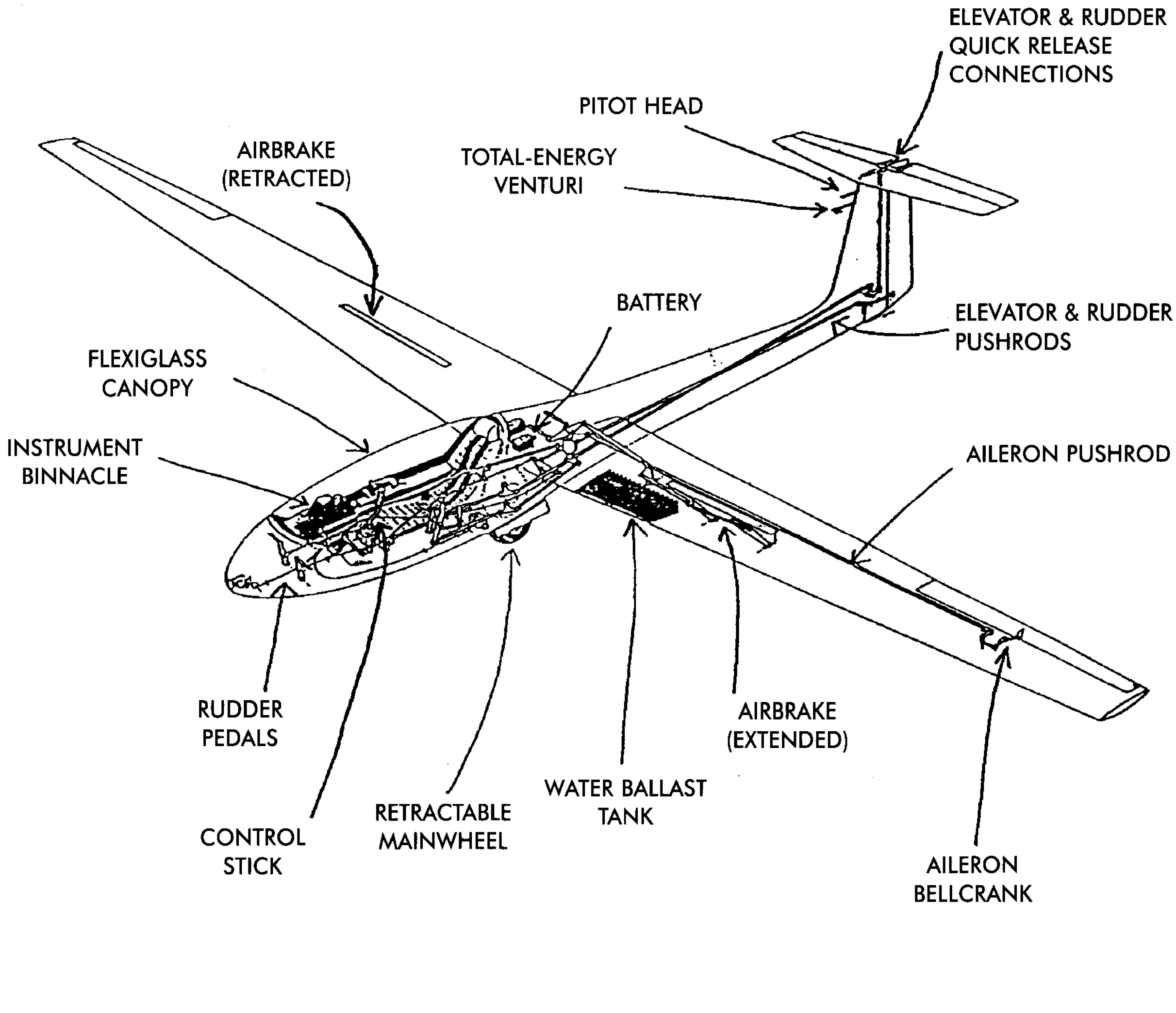
Stability in yaw, known as directional stability, is provided by the fin. When a glider yaws, the airflow blows against the side of the fin, producing a force which pushes the glider back into straight flight. This is similar to the behaviour of a weathercock on a church steeple, and in fact this kind of stability is sometimes known as weathercock stability. The fin provides directional stability.



Glider control

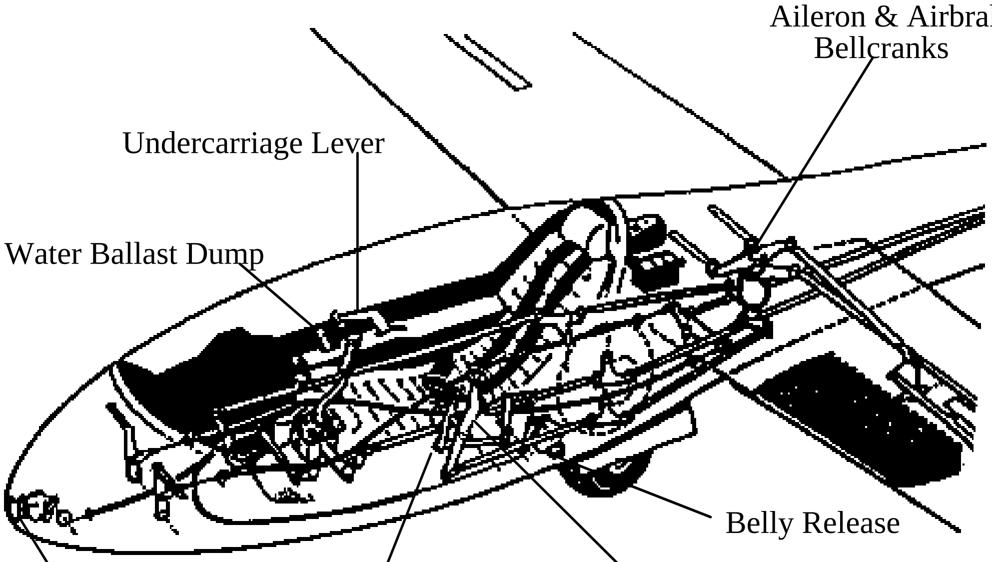
A glider is a stable platform which can be readily controlled.

The primary controls of a glider are the same as any other aeroplane. The elevator and ailerons are controlled by the stick and the rudder is controlled by the rudder pedals. The elevator is trimmed, either by a trim-tab or by a spring, and the airbrakes are used to control the rate of descent on the final landing approach. The diagram below shows the various controls and how they are installed and connected up in a glider.



GROB ASTIR GS STANDARD CLASS SAILPLANE

The close-up view of the cockpit of a glider which is shown here gives a more detailed picture of the operation of the control system of a modern glider.



In addition to the familiar stick and rudder pedal controls, note the additional controls positioned around the cockpit sides, one or two of which would seem a bit strange to a power-pilot's eyes. These are the airbrake control, on the left side of the cockpit, with the elevator trim right next to it. In this example, the elevator trim control is not connected to a tab, as in most light aircraft, but to two springs which are used to provide a trimming force on the elevator without the complication and drag of a tab. On the right of the cockpit is the large undercarriage retraction lever, which pulls the mainwheel up into a well behind the pilot. Just in front of the undercarriage lever is a smaller lever, which is used to dump water from the ballast tanks in the wings. The water is carried in order to increase the wing-loading for fast cross-country flying.

There are two towhooks, one in the nose for aerotowing and one under the belly for launching by winch or motor-car. They are both operated by a single knob in the cockpit.

The pilot is provided with a four-point safety harness, which gives good security during aerobatics and good protection in the event of an accident. A parachute is usually worn in this kind of glider and the cockpit canopy is easily jettisoned by means of a knob on the console under the instrument panel.

All the controls have quick-release connections, so that the glider can easily be de-rigged for transport in its trailer. Rigging the glider takes only about ten minutes and needs only three people. Safety inspections are always carried out after the glider has been rigged.

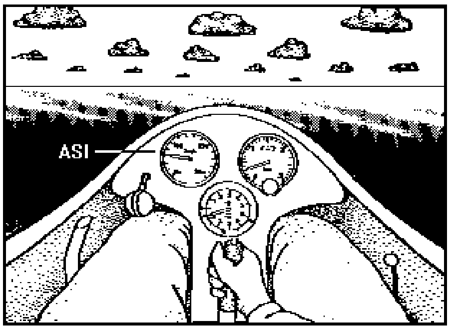
PRIMARY EFFECTS OF CONTROLS

Elevator

The effect of the elevator is to control the pitch of the glider. Firstly the glider is placed into its correct attitude with respect to the horizon. "Attitude" is the standard gliding term used to describe the position of the nose in relation to the horizon. When this is done, we have our "stable platform" referred to earlier. The illustration below shows how this appears from the cockpit of the glider.

Note nose position relative to horizon

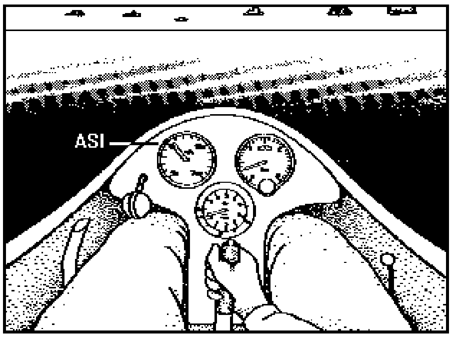
Note ASI reading



To observe the effect of the elevator, the stick is held lightly in the right hand and moved smoothly forward. Note that left-handed persons will need to get used to using the right hand on the stick. Look ahead at the horizon while doing this and it will be observed that the nose will go down below the previous attitude. The sound level in the cockpit increases as the speed builds up, due to the increase in speed of the airflow past the cockpit. During training, this sound level is a very important clue to changing speed in a glider. The increase in speed is confirmed by a glance at the Air Speed Indicator (ASI). See illustration below.

Nose lower than previous diagram

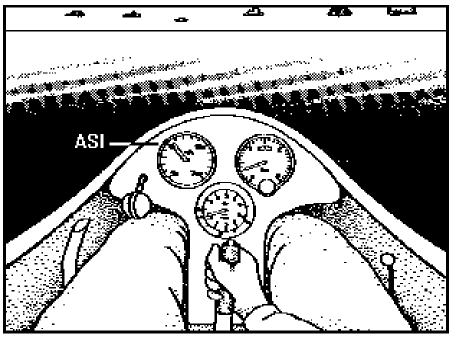
ASI reading higher



Still looking ahead, the stick is brought smoothly back and the nose will come up. The airflow noise will decrease and a glance at the ASI shows that the speed is decreasing. See below.

Nose higher than normal

ASI reading lower



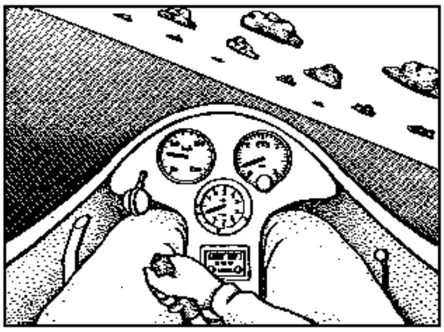
The elevator controls the attitude of the glider and therefore controls its speed. If the nose is low, the glider dives and the speed is high. If the nose is high, the glider flies slowly.

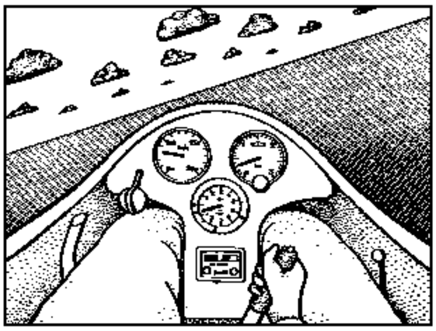
Stick forward, nose down, speed increases. Stick back, nose up and speed decreases. This is the only effect of the elevator. In a glider, **ATTITUDE = SPEED.**

Ailerons

The effect of the ailerons is to control the bank or roll of the glider. Starting at the stable platform again, the stick is held lightly in the right hand and moved smoothly to the left. The left wing will go down and it will keep going down if the stick is kept over to the left. If the stick is brought back to the central position (this is called "centralizing" the stick) the glider will stay banked over to the left - it will not return to the wings-level position of its own accord. If the pilot wants to get the wings level, the stick has to be moved in the opposite direction, in this case to the right. When this is done, the glider will start rolling to the right until it reaches the level position. The stick is then once again centralized and the glider will remain steady with its wings level. The glider is back at the stable platform.

It will be obvious that the same principles apply to banking to the right.





To recap, stick to the left and the glider banks to the left. Stick to the right and the glider banks to the right. The glider does not return to the level position when the stick is centralized - it stays at the bank angle chosen by the pilot. The stick needs to be moved in the opposite direction if the pilot wants to return the glider to level flight.

The primary effect of the ailerons is therefore bank or roll. It is necessary to bank the glider in order to make it turn. The ailerons are therefore the TURNING CONTROLS.

Aileron drag and adverse yaw.

Because of their long wingspan, fairly large ailerons and generally low operating speeds, gliders suffer from another effect of ailerons which becomes apparent as soon as they are used.

When the ailerons are deflected to make the glider bank, we get the results we want because the ailerons change the shape (aerofoil section) of the outer part of the wing. This in turn changes the amount of lift produced by each wingtip. For example, moving the stick to the left moves the left aileron up and the right aileron down. Lift over the left wingtip is reduced and lift over the right wingtip is increased. The glider therefore banks to the left. This is the effect we want and that's fine.

Unfortunately, an increase in lift brings with it an increase in INDUCED drag, and the effect of this is to YAW the glider in the opposite direction to which it is being banked. This unwanted yaw is adverse to the direction we want to bank, and for this reason is known as ADVERSE YAW. Adverse yaw, caused by aileron drag, is present on all gliders and cannot be eliminated. Glider pilots must therefore learn how to cope with it.

Rudder

The effect of the rudder is to control the yaw of the glider. Once again we start at the stable platform. Moving the right rudder-pedal forward (which naturally causes the left one to move back) results in the nose of the glider yawing (swinging) to the right.

One thing that is noticeable is that, when rudder is applied, the nose will only swing so far and then it will stop. This is because the rudder has only a limited ability to yaw the glider before it comes up against the yaw stability provided by the fin. Even though the rudder-pedals are kept deflected, the nose will only yaw so far and no further. This is the first clue that the rudder is not the control which turns the glider. The primary turning control is the aileron, not the rudder.

There is usually not much need for a pilot to yaw the glider during flight, although there might be some need to use the rudder to PREVENT yaw, in rough air for example. The really useful purpose of the rudder is to act as a helping or "balancing" control to cancel out the adverse yaw caused by the aileron drag described in the previous section. Every time the ailerons are used, either to turn the glider or to keep it on an even keel when it gets tipped up in rough air, the rudder is used in the same direction at the same time to prevent the nose yawing in the "wrong" direction.

This use of rudder in combination with the ailerons is known as "coordination". The coordination of the feet with the right hand is a very important part of learning to fly gliders.

It is mentioned above that the rudder may be used to prevent yaw developing, as well as to actually produce yaw. This principle is in fact true of all the controls in their respective axes of operation. For example, rough air can cause changes in nose attitude or bank angle and the appropriate control can be used to resist this unwanted change.

Definitions of control functions

Elevator is used to change speed or to STOP a change in speed.

Ailerons, suitably coordinated with rudder, are used to change direction or STOP a change in direction.

Rudder, as well as being used in coordination with ailerons, is used to yaw the glider or STOP the glider yawing.

SECONDARY EFFECTS

It has already been stated that the elevator has only one effect and does not have any further, or secondary, effect. This section is therefore concerned only with the secondary effects of bank and rudder.

Bank

If the glider is banked to one side or the other, but for some reason a properly-balanced turn does not follow, it is possible for a "sideslip" to develop towards the lower wing. If this happens, dihedral and pendulum effects (see lateral stability) will try to return the glider to straight flight. However, before this occurs, the slipping of the glider towards the lower wing will cause the glider's directional stability to yaw the nose towards the lower wing. The secondary effect of bank may therefore be YAW in the same direction as bank. It does however take some time to have any effect and is seldom encountered in practice. However, if it does develop and remains unchecked, it can eventually result in the glider entering a spiral dive.

Yaw

Secondary effect of rudder is roll in the same direction as yaw. When rudder is applied, the nose yaws to the side. If, for example, left rudder is applied, the nose swings to the left and this effectively increases the angle of attack of the right wing, which is now tending to point its tip into the oncoming airflow. The right wing therefore produces more lift than the left one and this results in the glider banking to the left, in the same direction as the applied rudder. This effect is used in radio-controlled model aircraft to turn the model when there may not be enough radio channels to enable ailerons to be fitted. Although it is very effective on models, it is nowhere near as effective on full-size gliders and can in fact be hazardous. It must never be used as a primary method of turning the aircraft.

ANCILLARY CONTROLS

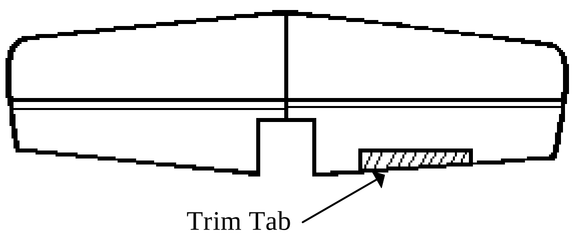
These are defined as controls other than the primary flight controls. They can be listed as follows:-

The cable/towrope release

The definition of this control is self-explanatory. It is usually a round knob or T-shaped handle situated so as to be accessible to the pilot's left hand. In some gliders it is not as accessible as it ought to be, which is a pity because it is a vital control which sometimes needs to be located and operated quickly. Whatever its size or shape, it is always coloured YELLOW by international agreement.

Elevator trim

The elevator trim enables the pilot to make an adjustment in order to allow the glider to be flown "hands-off" over a wide range of speeds and pilot weights. Most training gliders are fitted with elevator trim tabs, although it is nowadays more normal for high performance gliders to be fitted with a simple spring to hold the elevator in the position selected by the pilot. An elevator trim tab works as shown below. The "tab" is the small auxiliary flap inset into the trailing edge of one side of the elevator (some gliders have tabs on both sides). When deflected by the pilot moving the trim lever, the tab creates a moment about the elevator hinge line which "biases" the elevator in the opposite direction to the movement. The tab is the hatched area inset into the elevator.



The elevator trim can therefore be considered as a "labour-saving" device to save the pilot from having to keep a forward or backward force on the stick whenever he changes speed or when pilots of different weights fly the glider. The operating lever may be on the left or right side of the pilot, or in some cases even in the middle, on or near the stick. It is coloured GREEN by international agreement.

One important point about trimming. The speed of a glider is ALWAYS controlled by the elevator. The trim is used only to remove any residual force which may be felt on the stick.

Do not try to use the trim to control speed.

Spoilers

Spoilers are flat plates which can be extended upwards from the top surface of the wing in order to steepen the final approach path for landing. They achieve their effect by "spoiling" the airflow over the top surface of the wing. Spoilers are usually not very powerful, that is they do not enable a very steep approach path to be obtained. They would therefore not be adequate for an approach into a very small paddock over a line of tall trees. Spoilers may be set at any position within their operating range as required by the pilot to achieve the desired flight path and they may be varied in position during an approach. When extended, they usually cause a nose-down change in the glider's trim, which will need to be compensated by the pilot if the approach speed is to be accurately maintained.

Spoilers are operated by the pilot's left hand and the operating lever or knob is coloured BLUE by international agreement.

A typical spoiler installation (Scheibe SF25 "Falke" powered sailplane)

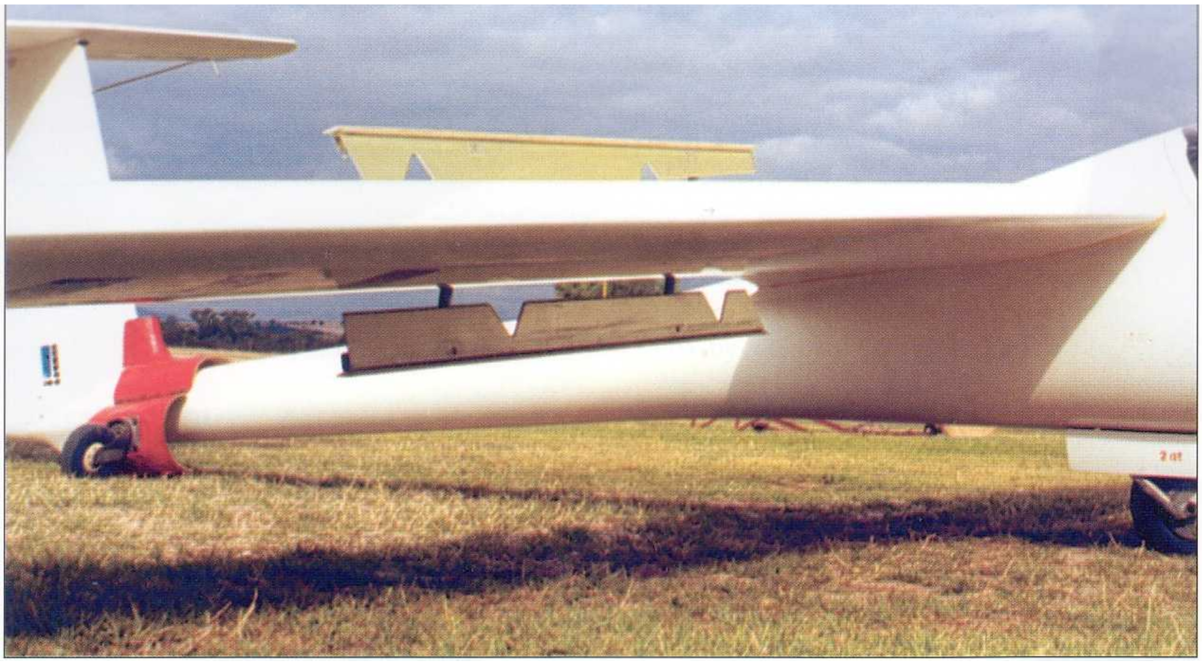
Airbrakes

The primary purpose of airbrakes in a glider is the same as spoilers - to steepen the approach path for landing. However, they are much more powerful in their effect than spoilers, because they are generally much bigger and often extend downward from the bottom of the wing as well as up from the top. They enable the pilot to make a steeper approach to land than with spoilers and are therefore much more suitable for outlanding in very small paddocks with obstacles on the boundary. They obtain their effect partly by spoiling the lift over the top surface of the wing and partly by causing a large increase in the total drag of the glider. This in turn makes it necessary for the pilot to lower the nose to maintain a constant approach speed, thereby steepening the approach path without causing an increase in speed.

A useful side-effect of airbrakes is that they are powerful enough to act as a speed-limiting device in a dive. The airbrakes fitted to modern gliders, if fully extended, will prevent the maximum allowable speed of the glider being exceeded in a dive up to a 30 degree angle. This can be useful if accidentally caught in cloud and having to dive out without risking overspeeding the structure.

Like spoilers, airbrakes are operated by the pilot's left hand and the operating lever is also coloured BLUE, because they are used for the same basic purpose as spoilers

Note: Most airbrakes and spoilers, when extended, cause an increase in stalling speed of between 2 and 5 knots. Therefore they should not be "fiddled with" near the ground until a pilot has some experience and is completely familiar with the individual glider's characteristics.



A typical "top and bottom" airbrake installation (SZD 48-1 Jantar)

Flaps

Quite a lot of modern gliders are fitted with flaps on the trailing edges of their wings. The purpose of flaps is to take advantage of a reduced stalling speed due to the increased camber of the wings when the flaps are lowered.

With flaps lowered, the following advantages are obtained:-

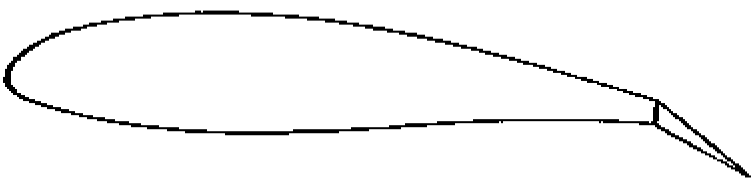
The pilot is able to fly more slowly with a good safety margin above the stalling speed.

This means a reduced radius of turn enabling small thermals to be used.

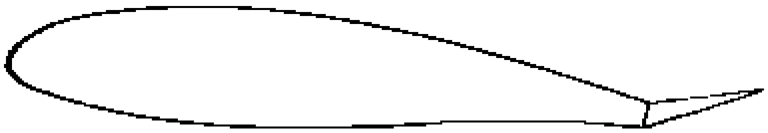
A slower approach speed may be used, still retaining an adequate margin above the stalling speed

Glider flaps also have the ability of be raised above the trailing edge of the wing into the "negative" or "reflex" position. This reduces the camber of the wing and has the effect of reducing drag at higher cruising speeds. This setting is very useful for cross-country flying.

The diagrams show the principles of operation of flaps in the downward (positive) and upward (negative) positions.



Flaps lowered. Increased camber, increased lift, reduced stalling speed, increased drag. Used for thermalling or approaching to land.

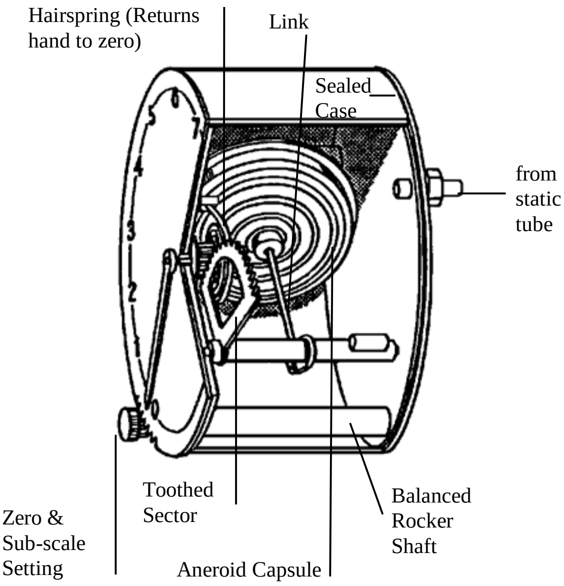


Flaps in "reflex" position. Reduced camber, less lift, higher stalling speed, reduced drag at high speeds. Used for cruising between thermals, never for circling and never for approaching to land.

GLIDER INSTRUMENTS

The instruments fitted to training gliders are usually quite simple, although single seaters can be more elaborately equipped, especially those used for competitions. A brief description of basic glider instruments, together with their principles of operation, follows.

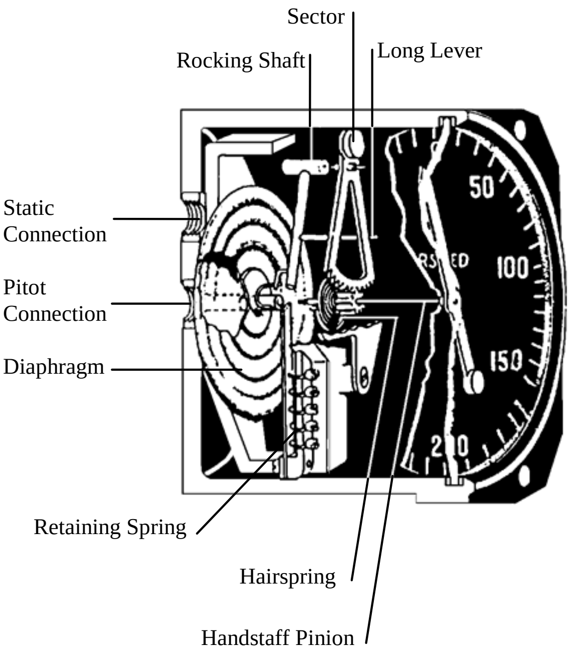
The altimeter



This instrument is simply an aneroid barometer, converted to read in feet instead of hectopascals of air pressure. Since an increase in height results in a decrease in air pressure, there is a direct relationship between the two and this can be shown clearly to the pilot. Most altimeters fitted to gliders are of the so-called "sensitive" type, which means that they have more than one hand, the better to show accurately the thousands and hundreds of feet at which the glider is flying. Similar to an ordinary domestic clock display, the large hand shows hundreds of feet and the small hand shows thousands. Many glider altimeters are of ex-military stock, purchased through disposals stores, and some of these have a third, very small, hand which shows tens of thousands of feet.

Altimeters have a "sub-scale", on which can be set the barometric pressure, using the little knob provided for the purpose. This can complicate the use of the altimeter and at this point it is best to refer to the chapter on altimetry in the GFA publication "Airways and Radio Procedures for Glider Pilots".

The airspeed indicator (ASI)



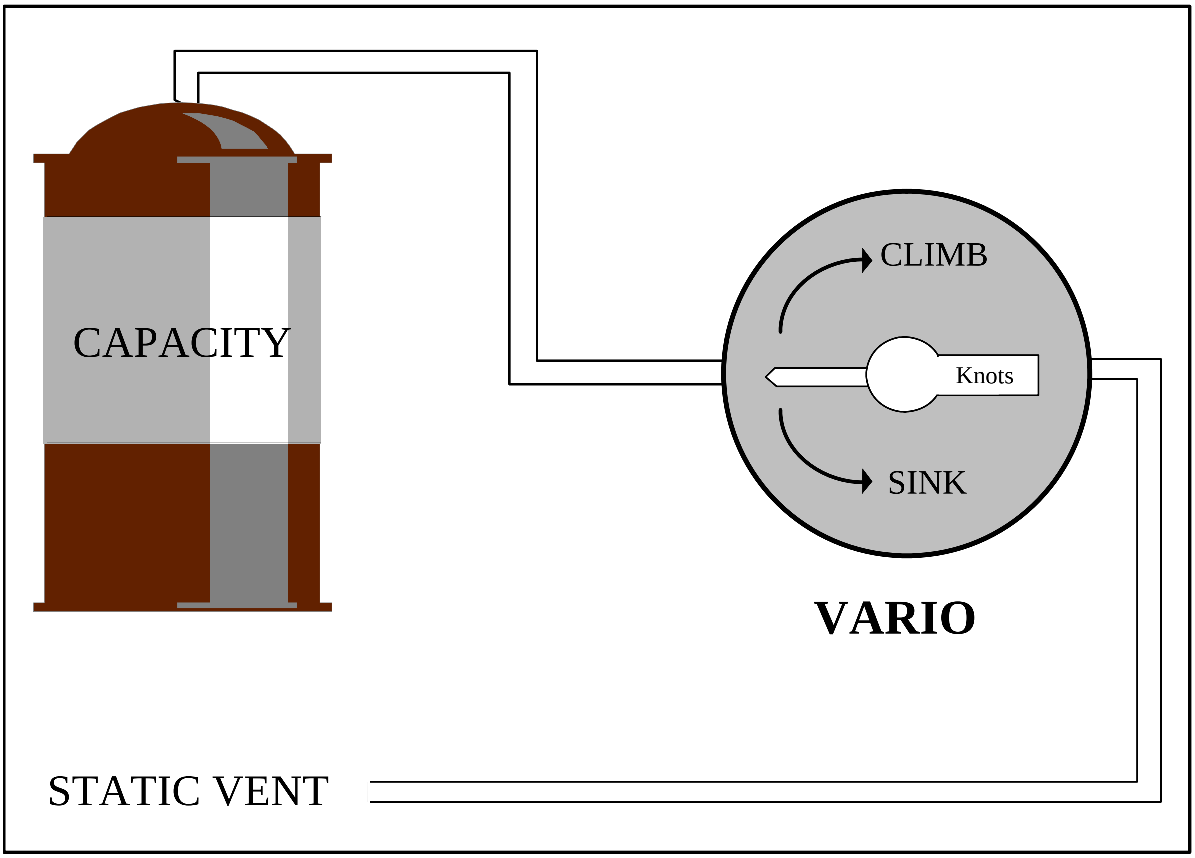
This instrument uses the pressure built up in front of the pitot head to move a needle around a dial, thus displaying the glider's speed through the air. The diagram explains how it works. Note that the pressures being handled by airspeed indicators are quite subtle and excessive pressure applied to the instrument through the pitot head will cause damage. Do not blow into pitot heads until properly taught how to do so when training to become a Daily Inspector. If you see anyone blowing into pitot heads (some people don't seem to be able to resist it), suspect that the instrument has suffered and report it to somebody.

In the lower levels of the atmosphere, where most training gliders operate, the airspeed indicator is relatively free from serious errors. However, the reduced pressure and density of the air at higher altitudes results in errors progressively creeping in. For information on these errors, refer to the "indicated airspeed and true airspeed" section in Chapter 7, Basic Airworthiness.

The variometer

Arguably the most important instrument in a glider, with the possible exception of the seat of the pilot's pants, the variometer is a very sensitive instrument for measuring rate of climb and descent. In its basic form, it works by measuring the rate at which air flows into and out of an enclosed container, which is a flask of standard .45 litre capacity. The air flowing in and out of the flask moves the needle in an up or down direction to indicate to the pilot whether the glider is climbing or descending.

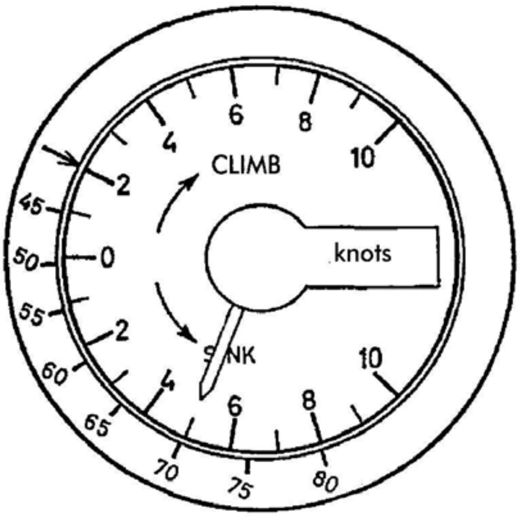
As the glider climbs in a thermal, it is moving into air of decreasing pressure. In order to equalise the pressures inside and outside of the flask, air flows out of the flask and passes through the instrument on its way. In doing so, it moves the needle to an "up" indication, by means of suitable linkages. The opposite happens when the glider descends into regions of increasing pressure.



The McCready ring

The American soaring pilot Paul McCready discovered that, during cross-country flying, it is possible to vary the glider's inter-thermal speed in accordance with the strength of the thermals being found. It is a simple enough theory; the stronger the thermals, the faster a pilot should fly between them in order to maximise cross-country speed.

Utilising the glider's "polar curve" of sink-rate versus airspeed, a McCready Ring can be constructed. This ring is fitted around the dial of the variometer and is controlled by the pilot. The following diagram illustrates the principle.



The arrow on the ring is rotated by the pilot to the **average** rate of climb experienced in the last thermal. Note that it is important to set it to the average climb rate, not the maximum seen by the pilot on the variometer. Most pilots are optimistic. If the ring is set too high for the prevailing conditions, the glider will be flown too fast and this may result in getting unnecessarily low on a cross-country flight and losing time by struggling back up again. In an extreme case, setting the ring too high may result in an outlanding.

Having set the ring, the pilot flies the glider in accordance with where the variometer pointer indicates in the sink range. If the pointer indicates 6 knots of sink and this shows 70 knots on the ring, accelerate the glider to 70 knots. This will of course increase the sink rate and the pointer will move further downwards. However, the situation rapidly stabilises and the pilot soon acquires the knack of varying the speed of the glider to suit the variations in sink rate, speeding up as sink increases, slowing down as sink decreases.

It might appear therefore that the progress of a glider on a cross-country flight somewhat resembles that of a dolphin. This is exactly what it does look like, and the technique of speeding up in strong sink, slowing down in lesser sink, is known as "dolphin soaring". This is often applied to the extent that, on a good day, a pilot may not bother to circle in all of the thermals, but will "dolphin soar" through most of them, only stopping to circle in one out or three or four encountered on track.

The compass

Gliders are usually fitted with a very simple magnetic compass, although more complicated devices are available for those who must have everything.

The compass in its simple form allows the pilot to see the glider's heading through the air. For more information on practical use of the compass in flight, see the section "Use of the compass" in the Basic Navigation chapter.

TURNING

Learning to turn a glider follows logically from learning the primary and secondary effects of the controls. More time is spent turning in gliders than in straight and level flight. It is therefore important that pilots correctly understand the forces that cause a glider to turn and how to influence those forces to achieve the desired result

Airmanship

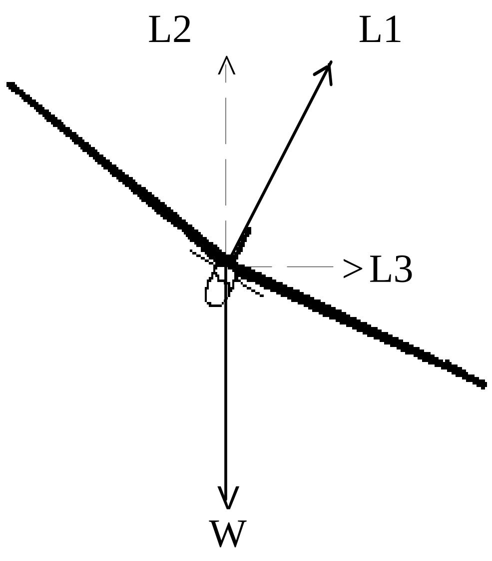
Before going on to consider the theory and practice of turning, the vital subject of airmanship must be understood. Airmanship is a difficult thing to define, but must certainly include an awareness of what is going on around the glider all the time. Pilots who possess good airmanship do not get surprised in the air, whether it be by the sudden appearance of another aircraft which had gone unnoticed or by the onset of a sudden major emergency such as tug engine failure.

The most obvious quality of airmanship from a trainee pilot's point of view, and one which is essential to acquire at an early stage, is LOOKOUT. A sharp lookout must be kept at all times. This is not difficult to do in a glider, because of the excellent visibility from glider cockpits. It is much more important in gliders than in any other kind of flying machine, except perhaps hang-gliders, because gliders are changing direction all the time in order to locate and use lift. Failure to keep a good lookout endangers ourselves and, more importantly, others sharing the air with us. For development of an effective lookout technique, see Chapter 4.

Good airmanship is easy to acquire and its value lasts a lifetime. Bad airmanship is a menace and lasts just as long. The only difference is the length of lifetime in each case.

Lookout is so important that an instructor will not allow a trainee pilot to turn unless that pilot has taken the basic precaution of ensuring that it is all clear. It is obvious that the main concentration of lookout will be in the direction we are about to turn; in other words towards the part of sky we are about to occupy. This careful lookout before turning must become an **INVARIABLE PRACTICE.**

Back to the turn itself. Remember that the primary turning controls are the ailerons, not the rudder. The ailerons are used to bank the glider and it is the bank angle which produces the force which turns the glider. In the diagram below, W = Weight, L1 = lift, tilted over due to bank angle, L2 = the component of lift opposing weight and L3 = component of lift producing turn.



When the glider is banked into a turn, the lift force is tilted over with it; remember that lift acts at right angles to the airflow around the wing. This tilted lift force, as well as trying to balance out the weight of the glider, also "pulls" the glider in the direction the pilot wants to turn. The more the glider is banked over, the greater the rate at which the glider will turn. The basic principle is as simple as that.

From the practical point of view, the glider is turned as follows.

Ensure a good LOOKOUT in the direction of intended turn.

Then look ahead over the nose and apply aileron and rudder together in the appropriate direction. Correct coordination can be checked by noting whether the nose moves smoothly around into the turn as the bank develops. If the nose "hesitates" before moving in the direction of the turn, insufficient rudder has been used in conjunction with the ailerons. If the nose moves noticeably in the turning direction before any bank has developed, too much rudder has been applied. The most common fault in the early stages of learning turns is insufficient rudder.

When sufficient bank has been applied (about 20 degrees is ample in the early stages of learning), centralize the ailerons and rudder. The glider will now be established in a gentle turn. Resume a lookout scan in the turning direction.

At this point you may notice a tendency for the glider's nose to drop slightly. This is normal in turning flight and is countered by a slight back pressure on the stick which must be maintained as long as the glider is turning. At steeper bank angles the nose-dropping tendency is more marked and needs a definite back movement.

During the turn, monitor and if necessary control bank angle with **A**ileron, suitably coordinated with **R**udder. Maintain correct nose attitude with **E**levator. Remember the little jingle **A-R-E**. "**ARE** we maintaining a correct turn?"

To come out of the turn, apply aileron and rudder in the opposite direction to the turn. The glider will roll towards the level position. Just before it becomes level (remember the glider has some inertia), centralize the aileron and rudder.

Relax whatever back pressure you had in the turn.

The most common faults in learning turns are -

- Failure to look out properly before turning.
- Insufficient rudder with aileron at turn entry
- Looking at ASI instead of monitoring nose attitude
- Failure to maintain back pressure in the turn.

NEVER try to turn a glider in flight by using rudder alone. Only on the ground is this acceptable.

STALLING

A stall in straight and level flight is quite simply a progressive loss of lift over the top section of the wing, causing the glider to lose height at an exaggerated rate. It occurs because the glider is made to fly in such a way that the angle of attack of the wing becomes too great and the smooth airflow breaks down over the top surface.

It is achieved by bringing the stick progressively further and further back, slowing the glider down and increasing the angle of attack of the wing until the stall occurs.

The purpose of stall training is twofold

(i) to learn to recognise the symptoms of an impending stall and to take the appropriate action to prevent it;

(ii) should the stall actually occur, to take the appropriate recovery action.

From the pilot's point of view, the symptoms of the stall occur progressively and are as follows: -

- Nose position higher than normal. Not necessarily a great deal higher, but noticeably so.
- A continuous backward movement of the stick.
- It becomes quieter in the cockpit because of the lower speed of the airflow past the canopy.
- A falling airspeed indication on the ASI
- Flying controls are less effective.
- There may be some mild buffeting of the airframe caused by the breakdown of the smooth airflow over the wing.

When the stall occurs, the airflow around the wing looks like this: -

The airflow in this picture (flowing over the wing from right to left) is shown by wool strips taped to the glider wing. The stall is well-developed, the strips indicating that the airflow is still normal near the leading edge (strips blowing straight back), but quite disturbed further back on the wing (strips blowing in all directions, even backwards in some cases).

When the stall actually occurs there are three possibilities in terms of glider behaviour, depending on the type of glider.

It may drop its nose quite markedly. If this does occur, it will occur despite the stick being fully back

It may not drop its nose, even though the stick is right on the back stop. In this kind of stall (e.g. Twin Astir), the rate of descent can be very high, although the nose position gives no clue to this.

One wing may go down, i.e. the glider may start rolling. This phenomenon, known as wing-drop, may occur in either of the above two types of stall and it may happen at exactly the same time as the stall occurs or perhaps just before.

Whichever of the three types of behaviour are apparent at the stall, the same action is taken by the pilot in all cases. This action is quite simply smooth and progressive forward movement of the stick to reduce the angle of attack and "unstall" the wing. Look outside at the horizon while you are doing this, to help orientation, reduce discomfort and make it more obvious when recovery action has been effective.

There is an interesting point to consider here. Although it is quite logical that a type "2" stall (no nose drop) can be cured by forward movement of the stick to lower the nose, it is not so readily apparent why it is necessary to move the stick forward when the nose has already dropped, or how it manages to fix a dropping wing.

As far as the nose-drop is concerned, it is important to realise that the wing is still stalled despite the nose pitching down. If the stick is held back, the nose will pitch strongly up again and go into another stall; it will go on doing this until the stick is moved forward to unstall the wing. Note that this forward movement of the stick when the nose goes down is not an instinctive reaction - all your training up to this point has tended to suggest that you should do the opposite. For this reason, stalling must be practised to the extent that forward movement of the stick when a stall is recognized becomes a CONDITIONED RESPONSE.

Loss of lateral damping

Wing drop occurs simply because one wing stalls before the other. When it stalls, lateral damping, the force which provides stability when the glider is rolling, is lost. There is nothing to stop the wing dropping further and further at the stall. In fact, the more the wing drops when stalled, the more it wants to keep dropping. In other words, the stability in roll provided by the lateral damping of an un-stalled wing becomes extreme **instability** in roll when the wing is stalled. The good news is that, when the stick is moved forward, the wing un-stalls, lateral damping is restored and the wing immediately stops going down.

A characteristic of stall recovery is that, once the stick has been moved positively forward and the angle of attack restored to below the stalling angle, the smooth airflow restores itself instantly and the wing immediately starts working in its normal way. However, care should be exercised in the use of the elevator after recovery from a stall. If the stick is pulled back too sharply too early after stall recovery, another stall could result. The average glider needs about three seconds to accelerate from the stalled condition to a safe speed of about 1.5 times the stalling speed during a normal stall recovery.

To summarise, always look ahead at the horizon during the first stages of stall recovery. Use the ASI as a back-up for ensuring that airspeed is building up. There is no point in diving in an exaggerated manner during stall recovery - it just wastes height. Develop a feel for when the glider has become unstalled and the nose can be safely restored to its normal position on the horizon.

STALLING IN A TURN - THE INCIPIENT SPIN

The last section mentioned wing-drop at the stall. If the wing-drop remains uncorrected, that is if the pilot fails to reduce the angle of attack of the wing by moving the stick forward, the glider could enter an incipient spin. The word incipient simply means undeveloped; the trick is to stop it from developing. We now know that the way to do this is by forward movement of the stick.

That's fine, but let us now take things a bit further. Suppose we do not recognise a wing drop early enough and as a result the wing drops quite a long way before we wake up. Let's say it goes to about 40 degrees of bank. As it goes down, it generates a very large angle of attack, resulting in loss of lateral damping and a tendency to keep rolling uncontrollably. The large angle of attack also produces a lot of induced drag.

The high value of induced drag causes YAW in the same direction as the dropping wing. This is the incipient stage of a spin. It is still a much undeveloped manoeuvre and if it is recognised at this stage can be very easily brought back under control by using forward stick movement (to unstall the wing) and just enough rudder to stop any yaw which may have developed.

Note that the use of the rudder is confined to small amounts at this stage - it is much more important to unstall the wing promptly by correct use of the elevator.

Although wing drop is quite easy to recognise in a straight stall, what if the glider stalls during a turn? This can occur, for example during a thermalling turn, if a pilot tries to fly very slowly in an attempt to reduce the radius of turn and get right into the centre of the thermal.

This is a much more difficult thing to recognise, because it is possible when turning for a glider to get close to the stall without the nose being noticeably higher than normal. The reason for this is related to the fact that the inner wing in a turn operates at a higher angle of attack than the outer wing and is therefore likely to reach the stalling angle while the outer wing is still below that critical angle. This means that the first thing a pilot might know about the onset of an incipient spin from turning flight is an "uncommanded" roll in the direction of the turn. In other words the glider increases its rate of roll without any aileron input from the pilot.

This is the first sign of a stalled inner wing in a turn and it is caused once again by the loss of lateral damping as the wing stalls. It is important to realise that, of all the conventional symptoms listed as being present in a level-flight stall, the only one which may be present during turning flight is the continuous backward movement of the stick.

The recovery action in this case is the same as that used to fix a wing-drop from a straight stall. The stick is moved smoothly and firmly forward and at the same time sufficient rudder should be applied to prevent the glider yawing any further towards the dropping wing. Your attention should be directed primarily OUTSIDE the cockpit during this process. As soon as lateral damping is restored and the wing has stopped dropping, level the wings by using the ailerons and fly the glider back to its usual attitude by normal use of all the controls.

THE FULLY-DEVELOPED SPIN

Spinning is an extension of the stalling and incipient spinning exercises. Once again, the purpose of the exercise is to acquaint pilots with the pre-spin symptoms so as to prevent the spin occurring and to expose pilots to the spin manoeuvre in order that the apprehension of spinning may be alleviated.

A spin may be defined as a manoeuvre in which the glider descends rapidly in a corkscrew flight path, with one wing completely stalled and the other wing either partially stalled or not stalled at all. Although many alarmist stories are told about spinning, it is important to realise that the recovery action is well-established and is always successful, if correctly applied.

There are three stages of a spin, as follows -

The incipient or undeveloped spin

The fully developed spin

The recovery.

The incipient stage has already been described and its recovery action dealt with. Once the fully-developed spin is achieved, however, we have an additional problem to consider, that of the actual rotation of the glider as it spins downwards. The inertia of the glider's mass rotating in the spin manoeuvre alters the nature of the recovery action. More on this in a moment.

Basically a glider spins because one wing stalls, sometimes of its own accord but usually under provocation from the pilot. This provocation usually takes the form of flying the glider too slowly (although not a great deal too slowly) and progressively applying more and more rudder in an attempt to "help" the glider round a turn.

Such wrong technique on the part of a pilot, which usually comes into play under stress, is unfortunately very common. It is also remarkably difficult to detect by any of the conventional methods of observing attitude and slip/skid. The stressful state of mind which causes this kind of regression in flying accuracy is frequently caused by trying to manoeuvre at low level, precisely the time when the consequences of a spin are at their worst.

The spin is a height-consuming manoeuvre. The height lost for each complete rotation of a spin varies from about 250ft in the case of a Kookaburra to nearly double that figure for an IS28B2 or a Janus.

Two things are therefore obvious, (i) the consequences of a low-level spin are likely to be disastrous, and (ii) practice spinning exercises are always done with plenty of height in hand and such exercises must be completed above 1000ft AGL (Above Ground Level).

The rotation in a spin is caused by the large difference in angle of attack between the inside and the outside wings. The inside wing has a very large angle of attack, total loss of lateral damping and an extremely high value of induced drag. The outside wing may be partially stalled, but observation of tufted wings in spinning manoeuvres suggests that it is usually not stalled at all.

The rolling motion in a spin ensures that the high AoA and the high induced drag on the inside wing are both maintained and this results in the glider automatically continuing to rotate in the spin. For this reason, the continuous rotation in the spin is known as AUTOROTATION. It will persist for as long as the conditions which were set up to produce the spin are maintained.

Recovery action from a fully developed spin is clear-cut and universal. Full rudder is applied in the opposite direction to the rotation, then the stick is moved steadily and progressively forward until the spin stops. At this point two problems need to be considered.

It is easy to become disorientated in the spin and become confused as to which way the glider is spinning. Practice removes most of this confusion.

The nose-down attitude in the spin is typically very steep. It is by no means an instinctive reaction to move the stick forward under these circumstances.

It is therefore necessary to practice spinning to the extent that confusion is eliminated and the recovery action, like that from a stall, becomes a CONDITIONED RESPONSE.

Once again, the sequence of actions to recover from a fully-developed spin are :-

Apply **full** opposite rudder.

Ensuring ailerons central, move the stick progressively forward until the spin stops.

When the spinning stops, centralize the rudder and recover from the resultant dive.

Notes:

Do not expect rudder alone to stop the rotation in a developed spin. Use of both controls is always necessary.

Because of the sideways airflow around the tail of the glider in a spin, the force required to apply full rudder is about three times that required in normal flight.

If recovery is not immediate despite correct and full recovery action being taken, don't panic. The glider will eventually recover.

Although correct spin recovery action is always successful, this is only so if the glider is flown within its limitations of weight and balance. See Chapter 7, Basic Airworthiness.

Safe speed near the ground

Prevention is better than cure. This is the origin of the "Safe speed near the ground" concept which is firmly locked into the GFA training system. The concept is quite simple - when under about 1000ft AGL the speed must be increased to at least 1.5 times the stalling speed (1.5Vs). This is designed to give an extra degree of protection in a situation where loss of control could leave insufficient height for recovery.

There is no flexibility in the "safe speed near the ground" rule

CHAPTER 3 - SELF-TEST QUESTIONNAIRE

Try these questions to test your understanding of the basic theory in Chapter 3. If you have trouble, refer back to the text of Chapter 3 for help.

What is the name given to the cross-sectional shape of the wing?

What three factors affect the lift produced by the wing?

In what direction does lift act?

Define wing-loading.

Name the two kinds of drag.

What provides stability in the pitching plane?

What is dihedral and what is its purpose?

What is the speed control in a glider?

What are the turning controls?

What is adverse yaw and what causes it?

Define "coordination".

What is the secondary effect of rudder?

What is the purpose of spoilers or airbrakes?

What happens to the stalling speed when flaps are lowered?

What action must never be omitted before turning?

What are the symptoms of a stall in straight flight?

What action must the pilot take if the glider stalls?

Is it possible to stall in a turn without a nose-high attitude?

What action must the pilot take if the glider stalls in a turn?

What is the recovery action from a fully-developed spin?

Define "safe speed near the ground". Calculate the speed to fly the circuit in a glider which stalls at 33 knots in straight flight.

How would you know if you had not applied enough rudder with aileron at the entry to a turn?

What is meant by the term "autorotation"?

If you are turning and the glider starts to noticeably increase its bank angle without any input from you, what is the problem and what would be your action?

What is another name for directional stability?

Define aspect-ratio.

What kind of drag is affected by a change in aspect-ratio?

Which force provides a glider with forward speed?

What happens to the stalling speed when the airbrakes are opened?

What is the other name for "glide-angle"?