Steep Turns

For the purposes of the pre-flight briefing a steep turn is defined as a turn of more than 30 degrees angle of bank, and common practice is to teach the exercise using a 45-degree angle of bank. Good training practice means higher angles of bank, up to 60 degrees, should also be experienced.

The steep gliding turn has been incorporated within this briefing as one method of presenting the material. Some organisations prefer to present a separate briefing on steep gliding turns (refer CFI).

Objectives

To change direction through 360 degrees at a constant rate, using 45 degrees angle of bank, maintaining a constant altitude and in balance.

To become familiar with the sensations of high bank angles and high rates of turn.

To turn at steep angles of bank while gliding.

Principles of Flight

Define the steep turn as a level turn at 45 degrees angle of bank.

Explain that the steep turn is taught to increase the student's coordination and skill, but the manoeuvre can also be used to avoid an encounter with cloud, terrain or other aircraft.

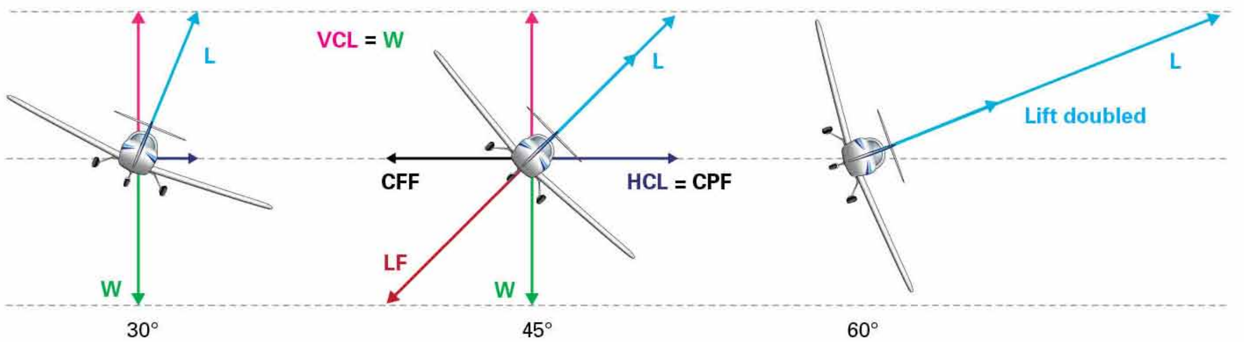
In this exercise the turn is continued for 360 degrees, rolling out on the original reference point, but if you were trying to avoid something you would not turn through a complete circle.

Steep gliding turns will also be covered as applicable to the *Forced Landing without Power* lessons, to cover the situation where the base turn needs to be steepened and to guard against the tendency to pull the nose up as a result of the high descent rate.

Start with a revision the forces in the level medium turn. There should be no need to start with an explanation of the forces in straight and level.

Because we wish to turn at a greater rate we need an increased turning (centripetal) force. To achieve this, we bank the aeroplane to a steeper angle than in a medium turn, thereby providing a greater acceleration towards the centre of the turn.

Figure 1



However this inclination of the lift vector decreases the vertical component of lift, therefore increased lift is required in order to provide sufficient vertical component to equal weight. This also further increases the horizontal component, tightening the turn even further.

> An example of increasing the bank even further should also be given. An angle of bank of 60 degrees is recommended (refer CFI) because at this point lift must be doubled to maintain altitude.

To this point the discussion has mostly been revision; now the acceleration forces acting on the aeroplane are described.

The acceleration force opposing CPF is centrifugal force (CFF). This is the acceleration that tries to pull the aeroplane out of the turn. These two 'forces', CPF and CFF, explain why water in a bucket does not fall out when the bucket is swung overhead.

The acceleration pushing the pilot into the seat is known as *load factor* (commonly referred to as G). This is equal and opposite to lift, and the wings must support it. Therefore, in level flight, where:

$$\frac{L}{W} = LF \quad \frac{1}{1} = 1 \text{ or } 1\,G$$

At 45 degrees the load factor is +1.41 and at 60 degrees angle of bank the load factor is doubled, +2 G, and the student will feel twice as heavy.

> Some organisations mention the effects of banking at 75 degrees (this may be deferred to Max Rate Turns, refer CFI) where the load factor is increased to +3.86 (nearly +4 G). This is usually done, only for the purpose of showing that the relationship between angle of bank and G, as well as stall speed, is not linear.

Although your drawing will show all the 'forces' equal and opposite to each other, the aeroplane is not in equilibrium!

Equilibrium is a state of nil acceleration or constant velocity, and velocity is a combination of speed and direction.

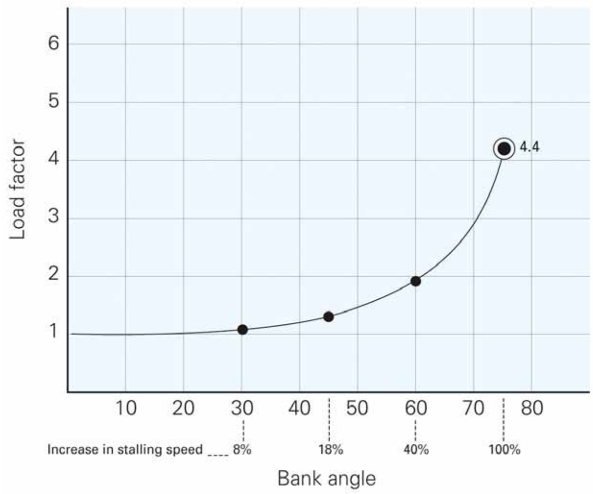
Therefore, although the student may have trouble understanding that the aeroplane is accelerating toward the centre of the turn, the aeroplane is clearly not maintaining a constant direction and therefore, by definition, cannot be in equilibrium.

The load factor is often referred to as *apparent weight* – because it is an acceleration (force) that the wings must support, similar to weight.

The effect of this increase in apparent weight, or load factor, on the stall speed is described.

The stall speed in a manoeuvre (V_{SM}) increases as the square root of the load factor (√LF). Assuming a stall speed of 50 knots in level flight, at 60 degrees angle of bank the stall speed will increase by the square root of the load factor +2 (√2), which is approx 1.4. This means that, at 60 degrees angle of bank, the stall speed is increased by 40% to 70 knots.

Figure 2



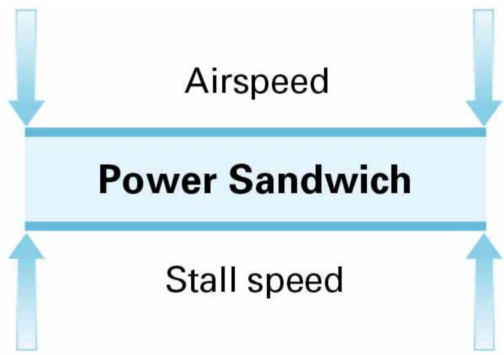
Presentation of the formulas in a preflight briefing is probably not required (refer CFI). However, the numerical effects are normally presented in a table type format.

Angle of Bank	Load Factor	% increase in stall speed	New stall speed
0	1		50
45	1.4	20	60
60	2	40	70
75	4	100	100

At the same time, because lift is increased by increasing the angle of attack, adversely affecting the L/D ratio, the drag also increases – by 100% at 45 degrees, and by 300% at 60 degrees angle of bank. This increase in drag, or reduction in L/D ratio, results in decreased airspeed.

This is an undesirable situation, with the stall speed increasing and airspeed decreasing. Therefore, the power is increased to combat the increased drag to maintain a margin over the stall speed. This can be referred to as a *power sandwich*.

Figure 3



In the medium level turn, the lift and drag increase and the adverse affect on the L/D ratio was so slight that the decrease in airspeed was ignored. However, as the increase in drag, load factor and stall speed is not linear, the effect of increasing drag can no longer be ignored. Therefore, any turn at angles of bank greater than 30 degrees requires an increase in power. At 45 degrees angle of bank this increase will be about 100–200 rpm.

> This explanation coincides with the patter of "through 30 degrees increase power" and is the reason why the steep turn is defined as angles of bank greater than 30 degrees.

All of these principles also apply to the steep gliding turn. However, power is obviously not available to oppose the increasing drag and therefore, at angles of bank greater than 30 degrees the airspeed must be increased with any angle of bank increases. At 45 degrees angle of bank, the airspeed is increased by 20% of the stall speed (about 5 to10 knots) to maintain a similar margin over the increased stall speed.

Revise adverse yaw and how it is countered. The amount of rudder required to overcome the adverse yaw is dependent on the rate of roll. The amount of rudder required is kept to a minimum by encouraging smooth control inputs. At low airspeeds the ailerons will need to be deflected further to achieve the same roll rate of higher airspeeds. This will significantly increase the induced drag and require more rudder to negate the adverse yaw. This will become apparent during gliding turns.

Considerations

Out of Balance

If the aeroplane is out of balance in the turn and rudder is applied to centre the ball, the further effects of rudder must be countered.

As rudder is applied, the correct angle of bank must be maintained with aileron. The resulting yaw will pitch the nose above or below the horizon, and therefore an adjustment to attitude will also be required to maintain constant altitude.

The Spiral Dive

A spiral dive is generally caused by over-banking.

If the angle of bank is permitted to increase, insufficient vertical component of lift will be produced, and the aeroplane will descend. The natural tendency is to attempt to pitch the nose up by increasing backpressure. Because of the high angle of bank, this tightens the turn and increases the rate of descent.

The symptoms of a spiral dive are a high angle of bank, rapidly increasing airspeed and increasing G.

The recovery method is to close the throttle, roll wings level, ease out of the dive and regain reference altitude.

The aeroplane's structural limits are reduced by 1/3 if manoeuvring in more than one plane. Therefore, firmly roll wings level before easing out of the dive.

Steep Gliding Turn

Spiralling down in the modern, low-drag light aeroplane can result in a very rapid increase in airspeed and exceeding the aeroplane's structural G limits. Most older training aeroplanes were not only built to be fully aerobatic but suffered from considerable drag, which generally meant the climb speed, cruise speed and top speed were all about the same, and as a consequence this manoeuvre was recommended as a way to get through a hole in the cloud below.

This is no longer the recommended way to deal with being stuck above cloud – the first step is to declare an emergency. With the current transponder coverage available in New Zealand, it is likely that ATC will quickly identify the aeroplane and provide a heading to steer to a cloud-free area, or another aircraft may be sent to assist.

If descent through a large hole is required (emphasise avoiding getting into this situation in the first place), select flap as required, power to idle and a 45 degree maximum angle of bank should be used, lowering the nose to maintain the selected speed.

Airmanship

State any organisation-imposed minimum altitude for the conduct of level steep turns, and the minimum descent altitude for steep gliding turn practise (refer CFI).

Revise **SADIE** checks and the need to counter the effect of wind to remain within the lateral boundaries of the training area.

Revise any VFR requirements considered relevant.

Ensure sick bags are on board.

Aeroplane Management

Above 30 degrees, power is increased with angle of bank. A 100-rpm increase at 45 degrees angle of bank is only a guide. Beware the rpm limit.

Human Factors

To minimise disorientation turns are made through 360 degrees, rolling out on the same reference point as that chosen before starting the turn. Because of the high rate of turn a prominent reference point should be chosen.

Revise the restrictions imposed by the airframe and the technique of looking in the opposite direction to the turn, starting at the tail and moving forward through the nose of the aeroplane and into the direction of the turn, so as to minimise possible conflict with aircraft directly behind.

In addition the effects of G on vision can be discussed.

For some students the sensation of the turn may be uncomfortable at first. The student should be informed that any discomfort will generally be overcome with exposure and practise, but to speak up early if they are uncomfortable.

Air Exercise

The air exercise discusses entering, maintaining and exiting the steep level turn at a bank angle of 45 degrees.

Entry

A reference altitude and prominent reference point are chosen and the lookout completed.

The aeroplane is rolled smoothly into the turn with aileron, and balance is maintained by applying rudder in the same direction as aileron to overcome adverse yaw.

Through 30 degrees angle of bank, power is increased with the increasing angle of bank, so that at 45 degrees angle of bank power has increased by about 100 rpm. At the same time, backpressure is increased on the control column to maintain altitude.

At 45 degrees, which is recognised through attitude and confirmed through instruments, a slight check will be required to overcome inertia in roll and rudder pressure will need to be reduced to maintain balance.

The indication of 45 degrees bank angle on the artificial horizon should be explained.

Maintaining

Maintaining the turn incorporates the **LAI** scan. Lookout into the turn is emphasised, and the attitude for 45 degrees angle of bank and level flight is maintained.

The effect of side-by-side seating on attitude recognition should be discussed, preferably with the aid of an attitude window.

During the turn, maintain the altitude with backpressure – provided that the angle of bank is correct. Maintain lookout, around airframe obstructions by moving the head.

If altitude is being gained or lost, first check angle of bank. If the angle of bank is correct, adjust backpressure to maintain constant altitude.

> Emphasis is placed here on establishing the correct angle of bank to prevent the onset of a spiral dive.

Exit

Look into the turn for traffic and the reference point. Allow for inertia by anticipating the roll out by about 20 degrees before the reference point.

> Anticipating by about half the bank angle encourages a smooth roll out that is easier to coordinate.

Smoothly roll wings level with aileron, balance with rudder in the same direction to overcome adverse yaw, and relax the backpressure to re-select the level attitude. Through ________ knots reduce power to cruise rpm.

Steep Gliding Turn

The steep gliding turn may be given either as a separate briefing before steep level turn revision (refer CFI) or demonstrated and practised in this lesson.

Enter a steep gliding turn from straight and level cruise by:

- applying carburettor heat,
- closing the throttle,
- rolling to 45 degrees angle of bank,
- maintaining height until the nominated airspeed is reached, and
- lowering the nose to maintain speed.
- Trim.

With the medium gliding turn established, the angle of bank and airspeed are increased at the same time, to 45 degrees angle of bank and ________ knots. This sequence is followed as it is the most probable sequence of events during a forced landing. If it is known beforehand that a large bank angle will be used, the airspeed could be increased in advance. However, it is more likely that the requirement for a steep turn will not be recognised until part way through the turn onto final with a tailwind on base.

In the steep gliding turn, the attitude must be adjusted to maintain the nominated airspeed.

> The decision to demonstrate an out-of-balance situation and the spiral dive should be referred to the CFI.

Airborne Sequence

The Exercise

The student should be capable of taking you to the training area, while operating as pilot-in-command. This will include making all the radio calls, making the decisions about which route to take, what altitude to climb to, and keeping a good lookout.

Once established in the training area, have the student practise medium level turns.

Emphasise lookout before and during the turn.

Take control and patter the student through the first turn. Then have them practise in that direction, while you correct any mistakes. Then have them try on their own, with no input from you until the end. Then take over and demonstrate in the other direction and follow the same sequence.

During one of the demonstrations, either left or right, ask the student to lift a foot off the floor so as to experience the effect of G.

Discourage any tendency by the student to lean out of the turn.

Once the student has completed satisfactory steep level turns both left and right, the effects of an out-of-balance situation and/or the spiral dive may be demonstrated or practised (refer CFI).

The majority of the lesson will be the student practising the turn. By the end of the lesson they should be able to tell you what they need to work on in future.

On your return to the aerodrome, it may be a good time to practise a forced landing, or an overhead rejoin.

After Flight

The next lesson will either be *Maximum Rate Turns* or *Wing-Drop Stalling*. Remind the student that you will be expecting them to practise these exercises solo, and to have shown improvement when you next fly with them.