INTRODUCTION
The maintenance of lift and control of an airplane in flight requires a certain minimum airspeed. This critical airspeed depends on certain factors, such as gross weight, load factors, and existing density altitude. The minimum speed below which further controlled flight is impossible is called the stalling speed. An important feature of pilot training is the development of the ability to estimate the margin of safety above the stalling speed. Also, the ability to determine the characteristic responses of any airplane at different airspeeds is of great importance to the pilot. The student pilot, therefore, must develop this awareness in order to safely avoid stalls and to operate an airplane correctly and safely at slow airspeeds.

SLOW FLIGHT
Slow flight could be thought of, by some, as a speed that is less than cruise. In pilot training and testing, however, slow flight is broken down into two distinct elements: (1) the establishment, maintenance of, and maneuvering of the airplane at airspeeds and in configurations appropriate to takeoffs, climbs, descents, landing approaches and go-arounds, and, (2) maneuvering at the slowest airspeed at which the airplane is capable of maintaining controlled flight without indications of a stall—usually 3 to 5 knots above stalling speed.

FLIGHT AT LESS THAN CRUISE AIRSPEEDS
Maneuvering during slow flight demonstrates the flight characteristics and degree of controllability of an airplane at less than cruise speeds. The ability to determine the characteristic control responses at the lower airspeeds appropriate to takeoffs, departures, and landing approaches is a critical factor in stall awareness.

As airspeed decreases, control effectiveness decreases disproportionately. For instance, there may be a certain loss of effectiveness when the airspeed is reduced from 30 to 20 m.p.h. above the stalling speed, but there will normally be a much greater loss as the airspeed is further reduced to 10 m.p.h. above stalling. The objective of maneuvering during slow flight is to develop the pilot’s sense of feel and ability to use the controls correctly, and to improve proficiency in performing maneuvers that require slow airspeeds. Maneuvering during slow flight should be performed using both instrument indications and outside visual reference. Slow flight should be practiced from straight glides, straight-and-level flight, and from medium banked gliding and level flight turns. Slow flight at approach speeds should include slowing the airplane smoothly and promptly from cruising to approach speeds without changes in altitude or heading, and determining and using appropriate power and trim settings. Slow flight at approach speed should also include configuration changes, such as landing gear and flaps, while maintaining heading and altitude.

FLIGHT AT MINIMUM CONTROLLABLE AIRSPEED
This maneuver demonstrates the flight characteristics and degree of controllability of the airplane at its minimum flying speed. By definition, the term “flight at minimum controllable airspeed” means a speed at which any further increase in angle of attack or load factor, or reduction in power will cause an immediate stall. Instruction in flight at minimum controllable airspeed should be introduced at reduced power settings, with the airspeed sufficiently above the stall to permit maneuvering, but close enough to the stall to sense the characteristics of flight at very low airspeed—which are sloppy controls, ragged response to control inputs, and difficulty maintaining altitude. Maneuvering at minimum controllable airspeed should be performed using both instrument indications and outside visual reference. It is important that pilots form the habit of frequent reference to the flight instruments, especially the airspeed indicator, while flying at very low airspeeds. However, a “feel” for the airplane at very low airspeeds must be developed to avoid inadvertent stalls and to operate the airplane with precision.

To begin the maneuver, the throttle is gradually reduced from cruising position. While the airspeed is decreasing, the position of the nose in relation to the horizon should be noted and should be raised as necessary to maintain altitude.

When the airspeed reaches the maximum allowable for landing gear operation, the landing gear (if equipped with retractable gear) should be extended and all gear down checks performed. As the airspeed reaches the maximum allowable for flap operation, full flaps...
should be lowered and the pitch attitude adjusted to maintain altitude. [Figure 4-1] Additional power will be required as the speed further decreases to maintain the airspeed just above a stall. As the speed decreases further, the pilot should note the feel of the flight controls, especially the elevator. The pilot should also note the sound of the airflow as it falls off in tone level.

As airspeed is reduced, the flight controls become less effective and the normal nosedown tendency is reduced. The elevators become less responsive and coarse control movements become necessary to retain control of the airplane. The slipstream effect produces a strong yaw so the application of rudder is required to maintain coordinated flight. The secondary effect of applied rudder is to induce a roll, so aileron is required to keep the wings level. This can result in flying with crossed controls.

During these changing flight conditions, it is important to retrim the airplane as often as necessary to compensate for changes in control pressures. If the airplane has been trimmed for cruising speed, heavy aft control pressure will be needed on the elevators, making precise control impossible. If too much speed is lost, or too little power is used, further back pressure on the elevator control may result in a loss of altitude or a stall. When the desired pitch attitude and minimum control airspeed have been established, it is important to continually cross-check the attitude indicator, altimeter, and airspeed indicator, as well as outside references to ensure that accurate control is being maintained.

The pilot should understand that when flying more slowly than minimum drag speed (LD/\text{MAX}) the airplane will exhibit a characteristic known as “speed instability.” If the airplane is disturbed by even the slightest turbulence, the airspeed will decrease. As airspeed decreases, the total drag also increases resulting in a further loss in airspeed. The total drag continues to rise and the speed continues to fall. Unless more power is applied and/or the nose is lowered, the speed will continue to decay right down to the stall. This is an extremely important factor in the performance of slow flight. The pilot must understand that, at speed less than minimum drag speed, the airspeed is unstable and will continue to decay if allowed to do so.

When the attitude, airspeed, and power have been stabilized in straight flight, turns should be practiced to determine the airplane’s controllability characteristics at this minimum speed. During the turns, power and pitch attitude may need to be increased to maintain the airspeed and altitude. The objective is to acquaint the pilot with the lack of maneuverability at minimum speeds, the danger of incipient stalls, and the tendency of the airplane to stall as the bank is increased. A stall may also occur as a result of abrupt or rough control movements when flying at this critical airspeed.

Abruptly raising the flaps while at minimum controllable airspeed will result in lift suddenly being lost, causing the airplane to lose altitude or perhaps stall.

Once flight at minimum controllable airspeed is set up properly for level flight, a descent or climb at minimum controllable airspeed can be established by adjusting the power as necessary to establish the desired rate of descent or climb. The beginning pilot should note the increased yawing tendency at minimum control airspeed at high power settings with flaps fully extended. In some airplanes, an attempt to climb at such a slow airspeed may result in a loss of altitude, even with maximum power applied.

Common errors in the performance of slow flight are:

- Failure to adequately clear the area.
- Inadequate back-elevator pressure as power is reduced, resulting in altitude loss.
- Excessive back-elevator pressure as power is reduced, resulting in a climb, followed by a rapid reduction in airspeed and “mushing.”
- Inadequate compensation for adverse yaw during turns.
- Fixation on the airspeed indicator.
- Failure to anticipate changes in lift as flaps are extended or retracted.
- Inadequate power management.
- Inability to adequately divide attention between airplane control and orientation.
STALLS
A stall occurs when the smooth airflow over the airplane’s wing is disrupted, and the lift degenerates rapidly. This is caused when the wing exceeds its critical angle of attack. This can occur at any airspeed, in any attitude, with any power setting. [Figure 4-2]

The practice of stall recovery and the development of awareness of stalls are of primary importance in pilot training. The objectives in performing intentional stalls are to familiarize the pilot with the conditions that produce stalls, to assist in recognizing an approaching stall, and to develop the habit of taking prompt preventive or corrective action.

Intentional stalls should be performed at an altitude that will provide adequate height above the ground for recovery and return to normal level flight. Though it depends on the degree to which a stall has progressed, most stalls require some loss of altitude during recovery. The longer it takes to recognize the approaching stall, the more complete the stall is likely to become, and the greater the loss of altitude to be expected.

RECOGNITION OF STALLS
Pilots must recognize the flight conditions that are conducive to stalls and know how to apply the necessary corrective action. They should learn to recognize an approaching stall by sight, sound, and feel. The following cues may be useful in recognizing the approaching stall.

- Vision is useful in detecting a stall condition by noting the attitude of the airplane. This sense can only be relied on when the stall is the result of an unusual attitude of the airplane. Since the airplane can also be stalled from a normal attitude, vision in this instance would be of little help in detecting the approaching stall.

- Hearing is also helpful in sensing a stall condition. In the case of fixed-pitch propeller airplanes in a power-on condition, a change in sound due to loss of revolutions per minute (r.p.m.) is particularly noticeable. The lessening of the noise made by the air flowing along the airplane structure as airspeed decreases is also quite noticeable, and when the stall is almost complete, vibration and incident noises often increase greatly.

- Kinesthesia, or the sensing of changes in direction or speed of motion, is probably the most important and the best indicator to the trained and experienced pilot. If this sensitivity is properly developed, it will warn of a decrease in speed or the beginning of a settling or mushing of the airplane.

- Feel is an important sense in recognizing the onset of a stall. The feeling of control pressures is very important. As speed is reduced, the resistance to pressures on the controls becomes progressively less. Pressures exerted on the controls tend to become movements of the control surfaces.
lag between these movements and the response of the airplane becomes greater, until in a complete stall all controls can be moved with almost no resistance, and with little immediate effect on the airplane. Just before the stall occurs, buffeting, uncontrollable pitching, or vibrations may begin.

Several types of stall warning indicators have been developed to warn pilots of an approaching stall. The use of such indicators is valuable and desirable, but the reason for practicing stalls is to learn to recognize stalls without the benefit of warning devices.

**FUNDAMENTALS OF STALL RECOVERY**

During the practice of intentional stalls, the real objective is not to learn how to stall an airplane, but to learn how to recognize an approaching stall and take prompt corrective action. [Figure 4-3] Though the recovery actions must be taken in a coordinated manner, they are broken down into three actions here for explanation purposes.

First, at the indication of a stall, the pitch attitude and angle of attack must be decreased positively and immediately. Since the basic cause of a stall is always an excessive angle of attack, the cause must first be eliminated by releasing the back-elevator pressure that was necessary to attain that angle of attack or by moving the elevator control forward. This lowers the nose and returns the wing to an effective angle of attack. The amount of elevator control pressure or movement used depends on the design of the airplane, the severity of the stall, and the proximity of the ground. In some airplanes, a moderate movement of the elevator control—perhaps slightly forward of neutral—is enough, while in others a forcible push to the full forward position may be required. An excessive negative load on the wings caused by excessive forward movement of the elevator may impede, rather than hasten, the stall recovery. The object is to reduce the angle of attack but only enough to allow the wing to regain lift.

Second, the maximum allowable power should be applied to increase the airplane’s airspeed and assist in reducing the wing’s angle of attack. The throttle should be promptly, but smoothly, advanced to the maximum allowable power. The flight instructor

![Figure 4-3. Stall recognition and recovery.](image-url)
should emphasize, however, that power is not essential for a safe stall recovery if sufficient altitude is available. Reducing the angle of attack is the only way of recovering from a stall regardless of the amount of power used.

Although stall recoveries should be practiced without, as well as with the use of power, in most actual stalls the application of more power, if available, is an integral part of the stall recovery. Usually, the greater the power applied, the less the loss of altitude.

Maximum allowable power applied at the instant of a stall will usually not cause overspeeding of an engine equipped with a fixed-pitch propeller, due to the heavy air load imposed on the propeller at slow airspeeds. However, it will be necessary to reduce the power as airspeed is gained after the stall recovery so the airspeed will not become excessive. When performing intentional stalls, the tachometer indication should never be allowed to exceed the red line (maximum allowable r.p.m.) marked on the instrument.

Third, straight-and-level flight should be regained with coordinated use of all controls.

Practice in both power-on and power-off stalls is important because it simulates stall conditions that could occur during normal flight maneuvers. For example, the power-on stalls are practiced to show what could happen if the airplane were climbing at an excessively nose-high attitude immediately after takeoff or during a climbing turn. The power-off turning stalls are practiced to show what could happen if the controls are improperly used during a turn from the base leg to the final approach. The power-off straight-ahead stall simulates the attitude and flight characteristics of a particular airplane during the final approach and landing.

Usually, the first few practices should include only approaches to stalls, with recovery initiated as soon as the first buffeting or partial loss of control is noted. In this way, the pilot can become familiar with the indications of an approaching stall without actually stalling the airplane. Once the pilot becomes comfortable with this procedure, the airplane should be slowed in such a manner that it stalls in as near a level pitch attitude as is possible. The student pilot must not be allowed to form the impression that in all circumstances, a high pitch attitude is necessary to exceed the critical angle of attack, or that in all circumstances, a level or near level pitch attitude is indicative of a low angle of attack. Recovery should be practiced first without the addition of power, by merely relieving enough back-elevator pressure that the stall is broken and the airplane assumes a normal glide attitude. The instructor should also introduce the student to a secondary stall at this point. Stall recoveries should then be practiced with the addition of power to determine how effective power will be in executing a safe recovery and minimizing altitude loss.

Stall accidents usually result from an inadvertent stall at a low altitude in which a recovery was not accomplished prior to contact with the surface. As a preventive measure, stalls should be practiced at an altitude which will allow recovery no lower than 1,500 feet AGL. To recover with a minimum loss of altitude requires a reduction in the angle of attack (lowering the airplane’s pitch attitude), application of power, and termination of the descent without entering another (secondary) stall.

**USE OF AILERONS/RUDDER IN STALL RECOVERY**

Different types of airplanes have different stall characteristics. Most airplanes are designed so that the wings will stall progressively outward from the wing roots (where the wing attaches to the fuselage) to the wingtips. This is the result of designing the wings in a manner that the wingtips have less angle of incidence than the wing roots. [Figure 4-4] Such a design feature causes the wingtips to have a smaller angle of attack than the wing roots during flight.

![Figure 4-4. Wingtip washout.](image-url)