PREFACE

This VFR Flight Training Handbook is developed by Global Aviation (a JAA Flight Training Organization GR-FTO-002 in Athens Greece) in accordance to JAR-FCL. Its main objective is to assist student pilots in familiarizing themselves with airplane flying. It introduces the basic pilot skills and knowledge that are essential for piloting airplanes. It provides information on transition to other airplanes and the operation of various airplane systems.

It is also beneficial to pilots who wish to improve their flying proficiency and aeronautical knowledge, those pilots preparing for additional certificates or ratings, and flight instructors engaged in the instruction of both students and certificated pilots. It introduces the future pilot to the realm of flight and provides information and guidance on the performance of procedures and maneuvers which have specific functions in various areas of operation. This handbook conforms to pilot training and certification concepts established by the Joint Aviation Authority (JAA). There are different ways of teaching as well as performing flight procedures and maneuvers, and many variations in the explanations of aerodynamic theories and principles. This handbook adopts a selective method and concept to flying airplanes. The discussions and explanations reflect the most commonly used practices and principles. Occasionally, the word “must” or similar language is used where the desired action is deemed critical.

This VFR Flight Training Handbook in combination with the Ground School Training material will provide the student pilot with all the theoretical knowledge needed to successfully pass the flight exercises’ completion standards. This handbook by no means replaces the theoretical material given by the Ground School; it only serves as supplementary material. The student pilot must spend at least a few hours preparing a flight session before arriving at the airport; this handbook will assist him/her to be better prepared.

The Head of Training

Marios Samprakos
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CHAPTER 1 - INTRODUCTION TO FLIGHT TRAINING

INTRODUCTION

Before beginning flight training, it is important to have a basic understanding of the responsibilities, safety regulations, and issues applicable to such an endeavor. This includes choice of a flight school, selected study materials, study habits, and the role of the instructor, student, and Joint Aviation Authorities (JAA). Safety, proper decision making, good habits, and collision avoidance are emphasized from the very beginning to ensure one gets started in the right direction.

CHOOSING A FLIGHT SCHOOL

Once a person has decided to become a pilot, the next consideration is where to attend flight school. Part of this consideration should be whether he or she is learning to fly for personal reasons, or planning to pursue a career in aviation.

Some sources for selecting a flight school may consist of the internet pages, aviation trade or flying magazines, or local airports. Many flight schools, colleges, and universities advertise in aviation magazines and offer excellent programs.

Some flight schools are referred to as “JAA-approved schools.” According to JAR-FCL the approved flight schools are the followings:

- **Register Facilities.** An RF provides flying training for Private pilot License in Single Engine Piston Airplanes only.
- **Flying Training Organizations (FTO).** An FTO is an organization staffed, equipped and operated in a suitable environment offering flying training, and/or synthetic flight instruction and/or theoretical knowledge instruction for specific training programmes.
- **Type Rating Training Organization (TRTO),** providing training for a specific airplane type in an already licensed pilot.

According to JAR-FCL a student pilot can achieve the Airline Transport License following the Integrated or the Modular training course. **GLOBAL** is an FTO registered as GR-FTO-002 which has the approval to provide Integrated and Modular courses. Qualified staff will guide the student to his selection.

INSTRUCTOR/STUDENT RELATIONSHIP

Every flight instructor has to comply with the approved flight training syllabus and the quality standard adopted by the Global Aviation. According to these standards, the flight instructor will provide guidance, and arrange for academic and flight training lessons. These lessons are presented in a logical manner to achieve desired goals. After each flight, the flight instructor will review the day’s lesson. This will be the time to clear up any questions because it is important that misconceptions be clarified while the subject is still fresh in mind.

This handbook provides the background and explanations of the academic principles and recommended flight training procedures needed to complete flight training. This handbook is an important tool in developing a sound background of knowledge and judgment needed to be a
competent and safe pilot. For example, a basic knowledge of aerodynamic principles helps the pilot to better understand what is needed to properly perform maneuvers, such as straight and level, turns, climbs, and descents.

Medical Certification

All pilots except must possess a valid medical certificate in order to exercise the privileges of their airman certificates. The periodic medical examinations required for medical certification are conducted by designated aviation medical examiners, which are physicians with a special interest in aviation safety and training in aviation medicine. The holder of a medical certificate shall be mentally and physically fit to exercise safely the privileges of the applicable license.

- Requirement for medical certificate. In order to apply for or to exercise the privileges of a license, the applicant or the holder shall hold a medical certificate issued in accordance with the provisions of JAR–FCL 3 (Medical) and appropriate to the privileges of the license.

- Aeromedical disposition. After completion of the examination the applicant shall be advised whether fit, unfit or referred to the Authority. The authorized medical examiner (AME) shall inform the applicant of any condition(s) (medical, operational or otherwise) that may restrict flying training and/or the privileges of any licensed issued.

Prior to beginning flight training, a flight instructor should interview the prospective student about any health conditions and determine the ultimate goal of the student as a pilot. Good advice would be to obtain the class of medical certificate required before beginning flight training. Finding out immediately whether the student is medically qualified could save time and money.

STUDY HABITS

The use of a training syllabus is an effective way to lead a student pilot through the proper steps in learning to fly safely.

When beginning flight training, the development of good study habits includes the practice of visualizing the flight instructor’s explanation plus those of the textbook.

Study habits include time spent with cockpit familiarization. This includes reviewing checklists, identifying controls, and learning the cockpit arrangement.

COLLISION AVOIDANCE

Air Law has established right-of-way rules, minimum safe altitudes, and VFR cruising altitudes to enhance flight safety. The pilot can contribute to collision avoidance by being alert and scanning for other aircraft. This is particularly important in the vicinity of an airport.

Effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10°, and should be observed for at least 1 second to enable detection. Although back and forth eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and adhere to it to assure optimum scanning.

If another aircraft is close enough to create a hazard, give way instead of waiting for the other pilot to respect the right-of-way.
Clearing Procedures

The following procedures and considerations should assist a pilot in collision avoidance under various situations.

- **Before Takeoff**—Prior to taxiing onto a runway or landing area in preparation for takeoff, scan the approach area for possible landing traffic, executing appropriate maneuvers to provide a clear view of the approach areas.

- **Climbs and Descents**—During climbs and descents in flight conditions which permit visual detection of other traffic, execute gentle banks left and right at a frequency which permits continuous visual scanning of the airspace.

- **Straight and Level**—During sustained periods of straight-and-level flight execute appropriate clearing procedures at periodic intervals.

- **Traffic Patterns**—Avoid entries into traffic patterns while descending.

- **Traffic at Very High Frequency Omnidirectional Range (VOR) sites**—Due to converging traffic, maintain extra vigilance in the vicinity of VOR’s and intersections.

- **Training Operations**—Maintain vigilance and do clearing turns prior to a practice maneuver. During instruction, the pilot may be asked to verbalize the clearing procedures (call out “clear left, right, above, and below”).

High-wing and low-wing aircraft have their respective blind spots. High-wing aircraft should momentarily raise their wing in the direction of the intended turn and look for traffic prior to beginning the turn. Low-wing aircraft should momentarily lower the wing.
CHAPTER 2 - PREFLIGHT, POSTFLIGHT, AND GROUND OPERATIONS

INTRODUCTION

This chapter discusses the basic procedures and techniques for proper preflight, postflight, and safe ground operations of an airplane. Proper preflight preparation is the foundation for safe flight operations. The manufacturer’s Airplane Flight Manual (AFM) and/or Pilot’s Operating Handbook (POH) should be used as the final authority for airplane operation.

PILOT ASSESSMENT

Perhaps the best place for pilots to begin a preflight is with themselves. Pilots will need to determine that they:

- are physically fit to make the flight;
- are in possession of a current medical certificate appropriate to the operation being conducted;
- are in possession of a valid pilot certificate appropriate to the operation being conducted.

The I’M SAFE checklist can be helpful to pilots in evaluating if they are in condition to conduct a flight safely. In doing this, pilots can ensure that they are not being impaired by:

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<tr>
<td>Medication</td>
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PREFLIGHT PREPARATION AND FLIGHT PLANNING

Whether the flight is to be local or cross-country, certain preflight items need to be reviewed and accomplished. The Training Syllabus and GLOBAL’s opera rating procedures requires that before each flight, the pilot shall become familiar with all available information concerning the flight.

For all flights, this includes runway lengths, and takeoff and landing distances. For flights not in the vicinity of an airport, the pilot must be familiar with:

- weather reports and forecasts;
- fuel requirements;
- load balance and performance for the specific flight
- alternate/diversion plans; and
- hours of operation for each airport included in the flight plan

The best sources of information for airplane performance data are the AFM/POH. The best sources for preflight weather and Notices to Airmen (NOTAM’s) information and AIP.
Based on a review of this information, particularly the weather conditions, fuel requirements, and pilot qualifications, a decision can be made on whether to begin the flight, or to cancel and reschedule.

AIRPLANE PREFLIGHT INSPECTION

The accomplishment of a safe flight includes a careful preflight inspection of the airplane. The preflight inspection is conducted with a checklist and helps determine if the airplane is in an airworthy condition for the intended flight.

Certificates and Documents

Airworthiness of the airplane is determined, in part, by the following certificates and documents, which must be on board the airplane when operated.

- Airworthiness certificate.
- Registration certificate.
- Radio Station.
- Operating limitations. These may take the form of an JAA-approved AFM/POH, placards, and instrument markings, or any combination of the above.

A complete preflight inspection includes a review of the airplane technical books.

Visual Inspection

The visual inspection should include potential obstructions in the parking area. Upon reaching the airplane, all tiedowns, control locks, window covers, cowling plugs, pitot covers, tow bars, and chocks should be removed. The general condition of the airplane should be checked for signs of damage and for fuel, oil, and hydraulic fluid leaks. Then, the preflight inspection should be performed in accordance with the printed checklist provided by the airplane manufacturer. While the battery master switch should not be on during the entire preflight, at one point it should be turned on briefly to ensure operation of landing-gear down lights, landing lights, taxi lights, strobes, rotating beacon, fuel gauges, and the stall warning device. If the flight is to be conducted at night, all lighting systems, both interior and exterior should be inspected.

Ice and frost may be factors during the winter months. There is no amount of safe ice for takeoff. Even a thin layer of frost can have a dramatic effect on a wing’s ability to produce lift. The best solution for deicing is a heated hangar. If such facilities are not available, aircraft deicing fluid can be used. Deicing fluids may be applied in a variety of concentrations and temperatures. Guidance and information on the use of deicing fluids can be found in the AFM/POH.

Under certain meteorological conditions, ice can reform after initial removal; therefore, a careful check of the airplane’s surfaces must be made just prior to takeoff.

Preheating the engine is advisable when temperatures are below freezing. The colder the temperature, the more a preheat becomes essential. Significant engine wear and even damage may occur from attempting to start a cold-soaked reciprocating engine in temperatures of approximately 20 °F or colder without a thorough preheat.

To ensure optimum visibility and collision avoidance, the windshield should be clean before flight. Plastic windows should be cleaned only with cleaners specifically approved for use on plastics. Do not use glass cleaners, gasoline, alcohol, or deicing fluids.
Particular attention should be paid to the fuel quantity, type and grade, and quality. Many fuel tanks are very sensitive to airplane attitude when attempting to fuel for maximum capacity. Nosewheel strut extension, both high as well as low, can significantly alter the attitude, and therefore the fuel capacity. The airplane attitude can, also be affected laterally by a ramp that slopes, leaving one wing slightly higher than another. Always confirm the fuel quantity indicated on the fuel gauges by visually inspecting the level of each tank.

The type, grade, and color of fuel are critical to safe operation. The approved fuel for the operation of GLOBAL’s airplanes is only aviation gasoline (AVGAS) grade. This type of fuel is low lead 100 octanes, or 100LL. AVGAS is dyed for easy recognition of its grade and has a familiar gasoline scent. Jet-A, or jet fuel, is a kerosene-based fuel for turbine powered airplanes. It has disastrous consequences when inadvertently introduced into reciprocating airplane engines. The piston engine operating on jet fuel may start, run, and power the airplane, but will fail because the engine has been destroyed from detonation. [Figure 2-1]

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<th>Product</th>
<th>Color Tint</th>
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<tr>
<td>Grade 80/87 AVGAS</td>
<td>Red</td>
</tr>
<tr>
<td>Grade 100LL AVGAS</td>
<td>Blue</td>
</tr>
<tr>
<td>Jet fuel (Jet A or A1)</td>
<td>Clear or straw</td>
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Jet fuel has a distinctive kerosene scent and is oily to the touch when rubbed between fingers. Jet fuel is clear or straw colored although it may appear dyed when mixed in a tank containing AVGAS. When a few drops of AVGAS are placed upon white paper, they evaporate quickly and leave just a trace of dye. In comparison, jet fuel is slower to evaporate and leaves an oily smudge. Jet fuel refueling trucks and dispensing equipment are marked with JET-A placards in white letters on a black background. Prudent pilots will supervise fueling to ensure that the correct tanks are filled with the right quantity, type, and grade of fuel. The pilot should always ensure that the fuel caps have been securely replaced following each fueling.

Engines certificated for grades 91/96 AVGAS will run satisfactorily on 100LL. The reverse is not true. Fuel of a lower grade/octane, if found, should never be substituted for a required higher grade. Detonation will severely damage the engine in a very short period of time.

Automotive gasoline is sometimes used as a substitute fuel in certain airplanes. Its use is acceptable only when the particular airplane has been issued a supplemental type certificate (STC) to both the airframe and engine allowing its use.

Checking for water and other sediment contamination is a key preflight element. Water tends to accumulate in fuel tanks from condensation, particularly in partially filled tanks. Because water is heavier than fuel, it tends to collect in the low points of the fuel system. Water can also be introduced into the fuel system from deteriorated gas cap seals exposed to rain, or from the supplier’s storage tanks and delivery vehicles. Sediment contamination can arise from dust and dirt entering the tanks during refueling, or from deteriorating rubber fuel tanks or tank sealant.

The best preventive measure is to minimize the opportunity for water to condense in the tanks. The fuel tanks should be completely filled with the proper grade of fuel after each flight, or at least filled after the last flight of the day. The more fuel there is, the less opportunity for condensation to occur. Keeping fuel tanks filled is also the best way to slow the aging of rubber fuel tanks and tank sealant.
Sufficient fuel should be drained from the fuel strainer quick drain and from each fuel tank sump to check for fuel grade/color, water, dirt, and smell. If water is present, it will usually be in bead-like droplets, different in color (usually clear, sometimes muddy), in the bottom of the sample. In extreme cases, do not overlook the possibility that the entire sample, particularly a small sample, is water. If water is found in the first fuel sample, further samples should be taken until no water appears. Significant and/or consistent water or sediment contamination is ground for further investigation by qualified maintenance personnel. Each fuel tank sump should be drained during preflight and after refueling.

The oil level should be checked during each preflight and rechecked with each refueling. Reciprocating airplane engines can be expected to consume a small amount of oil during normal operation. If the consumption grows or suddenly changes, qualified maintenance personnel should investigate. If line service personnel add oil to the engine, the pilot should ensure that the oil cap has been securely replaced.

**MINIMUM EQUIPMENT LISTS AND OPERATIONS WITH INOPERATIVE EQUIPMENT**

The approved operating manual of GLOBAL requires that all aircraft instruments and installed equipment is operative prior to each departure. The minimum equipment list (MEL) concept allows operation with inoperative items determined to be nonessential for safe flight. Its popularity is due to simplicity and minimal paperwork. When inoperative equipment is found during preflight or prior to departure, the decision should be to cancel the flight, obtain maintenance prior to flight, or to defer the item or equipment.

Maintenance deferrals are not used for in-flight discrepancies. The manufacturer’s AFM/POH procedures are to be used in those situations. If the inoperative item is not required, and the airplane can be safely operated without it, the deferral may be made. The inoperative item shall be deactivated or removed and an INOPERATIVE placard placed near the appropriate switch, control, or indicator. If deactivation or removal involves maintenance (removal always will), it must be accomplished by certificated maintenance personnel.

**COCKPIT MANAGEMENT**

After entering the airplane, the pilot should first ensure that all necessary equipment, documents, checklists, and navigation charts appropriate for the flight are on board. If a portable intercom, headsets, or a hand-held global positioning system (GPS) are used, the pilot is responsible for ensuring that the routing of wires and cables does not interfere with the motion or the operation of any control.

Regardless of what materials are to be used, they should be neatly arranged and organized in a manner that makes them readily available. The cockpit and cabin should be checked for articles that might be tossed about if turbulence is encountered. Loose items should be properly secured. All pilots should form the habit of good housekeeping.

The pilot must be able to see inside and outside references. If the range of motion of an adjustable seat is inadequate, cushions should be used to provide the proper seating position. When the pilot is comfortably seated, the safety belt and shoulder harness (if installed) should be fastened and adjusted to a comfortably snug fit. The shoulder harness must be worn at least for the takeoff and
landing, unless the pilot cannot reach or operate the controls with it fastened. The safety belt must be worn at all times when the pilot is seated at the controls. If the seats are adjustable, it is important to ensure that the seat is locked in position. Accidents have occurred as the result of seat movement during acceleration or pitch attitude changes during takeoffs or landings. When the seat suddenly moves too close or too far away from the controls, the pilot may be unable to maintain control of the airplane.

The operating procedures requires the pilot to ensure that each person on board is briefed on how to fasten and unfasten his or her safety belt and, if installed, shoulder harness. This should be accomplished before starting the engine, along with a passenger on proper use of safety equipment and exit information. Airplane manufacturers have printed briefing cards available, similar to those used by airlines, to supplement the pilot’s briefing.

**USE OF CHECKLISTS**

The importance of consistent use of the checklist cannot be overstated in pilot training. A major objective in primary flight training is to establish habit patterns that will serve pilots well throughout their entire flying career. Checklists provide a logical and standardized method to operate a particular make and model airplane. Following a checklist reinforces the use of proper procedures throughout all major phases of flight operations. For normal operations these phases include:

- Preflight Inspection.
- Before Engine Starting.
- Use of External Power.
- Engine Starting.
- Before Taxiing.
- Before Takeoff.
- Climb.
- Cruise.
- Descent.
- Before Landing.
- Balked Landing.
- After-landing.
- Shutdown.
- Postflight/ELT Check.

Additional procedures are provided for abnormal and emergency operations, as appropriate to the airplane. Supplemental information, such as performance data or optional equipment operation, may also be contained in the checklist.

Some general aviation airplanes have checklists for certain phases of flight on panel-mounted placards or printed on sun visors. Regardless of the format, the checklist should be an integral part of the pilot’s operation of the airplane.

There are two primary methods of checklist usage, “read and do” and “do and verify.”

The read and do method is when the pilot picks up a checklist, refers to an item, and sets the condition. The items for any particular phase of flight would all be accomplished before the checklist
Another acceptable method is to set the condition of the items for a particular phase of operation from memory or flow pattern. Then the checklist is picked up and read to verify that the appropriate condition for each item in that phase has been set. It is not wise for a pilot to become so reliant upon a flow pattern that he or she fails to verify with a checklist. Checking important items solely from memory is not an acceptable substitute for checklists.

GROUND OPERATIONS

It is important that a pilot operates an airplane safely on the ground. This includes being familiar with standard hand signals that are used by ramp personnel. [Figure 2-2]

Starting the Engine

The specific procedures for engine starting will not be discussed here since there are as many different methods as there are different engines, fuel systems, and starting conditions. The before engine starting and engine starting checklist procedures should be followed. There are, however, certain precautions that apply to all airplanes.

Some pilots have started the engine with the tail of the airplane pointed toward an open hangar door, parked automobiles, or a group of bystanders. This is not only discourteous, but may result in personal injury and damage to the property of others. Propeller blast can be surprisingly powerful.

When ready to start the engine, the pilot should look in all directions to be sure that nothing is or will be in the vicinity of the propeller. This includes nearby persons and aircraft that could be struck by the propeller blast or the debris it might pick up from the ground. The anticollision light should be turned on prior to engine start, even during daytime operations. At night, the position (NAV) lights should also be on.

The pilot should always call CLEAR out of the side window and wait for a response from persons who may be nearby before activating the starter.

When activating the starter, one hand should be kept on the throttle. This allows prompt response if the engine falters during starting, and allows the pilot to rapidly retard the throttle if revolutions per minute (RPM) are excessive after starting. A low RPM setting (800 to 1,000) is recommended immediately following engine start. It is highly undesirable to allow the RPM to race immediately after start, as there will be insufficient lubrication until the oil pressure rises. In freezing temperatures, the engine will also be exposed to potential mechanical distress until it warms and normal internal operating clearances are assumed.

As soon as the engine is operating smoothly, the oil pressure should be checked. If it does not rise to the manufacturer’s specified value, the engine may not be receiving proper lubrication and should be shut down immediately to prevent serious damage.

Although quite rare, the starter motor may remain on and engaged after the engine starts. This can be detected by a continuous very high current draw on the ammeter. Some airplanes also have a starter engaged warning light specifically for this purpose. The engine should be shut down immediately should this occur.

Starters are small electric motors designed to draw large amounts of current for short periods of cranking. Should the engine fail to start readily, avoid continuous starter operation for periods longer
than 30 seconds without a cool down period of at least 30 seconds to a minute (some AFM/POH specify even longer). Their service life is drastically shortened from high heat through overuse.

**Hand Propping**

Even though most airplanes are equipped with electric starters, it is helpful if a pilot is familiar with the procedures and dangers involved in starting an engine by turning the propeller by hand (hand propping). Due to the associated hazards, this method of starting should be used only when absolutely necessary and when proper precautions have been taken.

An engine must never be hand propped unless two people, both familiar with the airplane and hand propping techniques, are available to perform the procedure. The person pulling the propeller blades through directs all activity and is in charge of the procedure. The other person, thoroughly familiar with the controls, must be seated in the airplane with the brakes set. As an additional precaution, chocks should be placed in front of the main wheels. If this is not feasible, the airplane’s tail should be securely tied down. Never allow a person unfamiliar with the controls to occupy the pilot’s seat when hand propping. The procedure should never be attempted alone.

![Standard hand signals.](image)

Figure 2-2.—Standard hand signals.
When hand propping is necessary, the ground surface near the propeller should be stable and free of debris. Unless a firm footing is available, consider relocating the airplane. Loose gravel, wet grass, mud, oil, ice, or snow might cause the person pulling the propeller through to slip into the rotating blades as the engine starts.

Both participants should discuss the procedure and agree on voice commands and expected action. To begin the procedure, the fuel system and engine controls (tank selector, primer, pump, throttle, and mixture) are set for a normal start. The ignition/magneto switch should be checked to be sure that it is OFF. Then the descending propeller blade should be rotated so that it assumes a position slightly above the horizontal. The person doing the hand propping should face the descending blade squarely and stand slightly less than one arm’s length from the blade. If a stance too far away were assumed, it would be necessary to lean forward in an unbalanced condition to reach the blade. This may cause the person to fall forward into the rotating blades when the engine starts.

The procedure and commands for hand propping are:

- Person out front says, “GAS ON, SWITCH OFF, THROTTLE CLOSED, BRAKES SET.”
- Pilot seat occupant, after making sure the fuel is ON, mixture is RICH, ignition/magneto switch is OFF, throttle is CLOSED, and brakes SET, says, “GAS ON, SWITCH OFF, CLOSED THROTTLE, BRAKES SET.”
- Person out front, after pulling the propeller through to get the engine primed and ready to start, says, “BRAKES AND CONTACT.”
- Pilot seat occupant checks the brakes SET and turns the ignition switch ON, then says, “BRAKES AND CONTACT.”

The propeller is swung by forcing the blade downward rapidly, pushing with the palms of both hands. If the blade is gripped tightly with the fingers, the person’s body may be drawn into the propeller blades should the engine misfire and rotate momentarily in the opposite direction. As the blade is pushed down, the person should step backward, away from the propeller. If the engine does not start, the propeller should not be repositioned for another attempt until it is certain the ignition/magneto switch is turned OFF.

The words CONTACT (mags ON) and SWITCH OFF (mags OFF) are used because they are significantly different from each other. Under noisy conditions or high winds, the words CONTACT and SWITCH OFF are less likely to be misunderstood than SWITCH ON and SWITCH OFF.

When removing the wheel chocks after the engine starts, it is essential that the pilot remember that the propeller is almost invisible. Incredible as it may seem, serious injuries and fatalities occur when people who have just started an engine walk or reach into the propeller arc to remove the chocks. Before the chocks are removed, the throttle should be set to idle and the chocks approached from the rear of the propeller. Never approach the chocks from the front or the side.

The procedures for hand propping should always be in accordance with the manufacturer’s recommendations and checklist. Special starting procedures are used when the engine is already warm, very cold, or when flooded or vapor locked. There will also be a different starting procedure when an external power source is used.
TAXIING

The following basic taxi information is applicable to nosewheel airplanes. Taxiing is the controlled movement of the airplane under its own power while on the ground. Since an airplane is moved under its own power between the parking area and the runway, the pilot must thoroughly understand and be proficient in taxi procedures.

An awareness of other aircraft that are taking off, landing, or taxiing, and consideration for the right-of-way of others is essential to safety. When taxiing, the pilot’s eyes should be looking outside the airplane, to the sides, as well as the front. The pilot must be aware of the entire area around the airplane to ensure that the airplane will clear all obstructions and other aircraft. If at any time there is doubt about the clearance from an object, the pilot should stop the airplane and have someone check the clearance. It may be necessary to have the airplane towed or physically moved by a ground crew.

It is difficult to set any rule for a single, safe taxiing speed. What is reasonable and prudent under some conditions may be imprudent or hazardous under others. The primary requirements for safe taxiing are positive control, the ability to recognize potential hazards in time to avoid them, and the ability to stop or turn where and when desired, without undue reliance on the brakes. Pilots should proceed at a cautious speed on congested or busy ramps. Normally, the speed should be at the rate where movement of the airplane is dependent on the throttle. That is, slow enough so when the throttle is closed the airplane can be stopped promptly. When yellow taxiway centerline stripes are provided, they should be observed unless necessary to clear airplanes or obstructions.

When taxiing, it is best to slow down before attempting a turn. Sharp, high-speed turns place undesirable side loads on the landing gear and may result in an uncontrollable swerve or a ground loop. This swerve is most likely to occur when turning from a downwind heading toward an upwind heading. In moderate to high-wind conditions, pilots will note the airplane’s tendency to weathervane, or turn into the wind when the airplane is proceeding crosswind.

When taxiing at appropriate speeds in no-wind conditions, the aileron and elevator control surfaces have little or no effect on directional control of the airplane. The controls should not be considered steering devices and should be held in a neutral position. Their proper use while taxiing in windy...
conditions will be discussed later. [Figure 2-3]

Steering is accomplished with rudder pedals and brakes. To turn the airplane on the ground, the pilot should apply rudder in the desired direction of turn and use whatever power or brake that is necessary to control the taxi speed. The rudder pedal should be held in the direction of the turn until just short of the point where the turn is to be stopped. Rudder pressure is then released or opposite pressure is applied as needed.

More engine power may be required to start the airplane moving forward, or to start a turn, than is required to keep it moving in any given direction. When using additional power, the throttle should immediately be retarded once the airplane begins moving, to prevent excessive acceleration.

When first beginning to taxi, the brakes should be tested for proper operation as soon as the airplane is put in motion. Applying power to start the airplane moving forward slowly, then retarding the throttle and simultaneously applying pressure smoothly to both brakes does this. If braking action is unsatisfactory, the engine should be shut down immediately.

Downwind taxiing will usually require less engine power after the initial ground roll is begun, since the wind will be pushing the airplane forward. To avoid overheating the brakes when taxiing down wind, keep engine power to a minimum. Rather than continuously riding the brakes to control speed, it is better to apply brakes only occasionally. Other than sharp turns at low speed, the throttle should always be at idle before the brakes are applied. It is a common student error to taxi with a power setting that requires controlling taxi speed with the brakes. This is the aeronautical equivalent of driving an automobile with both the accelerator and brake pedals depressed.

When taxiing with a quartering headwind, the wing on the upwind side will tend to be lifted by the wind unless the aileron control is held in that direction (upwind aileron UP). Moving the aileron into the UP position reduces the effect of the wind striking that wing, thus reducing the lifting action. This control movement will also cause the downwind aileron to be placed in the DOWN position, thus a small amount of lift and drag on the downwind wing, further reducing the tendency of the upwind wing to rise.

When taxiing with a quartering tailwind, the elevator should be held in the DOWN position, and the upwind aileron, DOWN. Since the wind is striking the airplane from behind, these control positions reduce the tendency of the wind to get under the tail and the wing and to nose the airplane over.

The application of these crosswind taxi corrections helps to minimize the weathervaning tendency and ultimately results in making the airplane easier to steer. Normally, all turns should be started using the rudder pedal to steer the nosewheel. To tighten the turn after full pedal deflection is reached; the brake may be applied as needed. When stopping the airplane, it is advisable to always stop with the nosewheel straight ahead to relieve any side load on the nosewheel and to make it easier to start moving ahead.

During crosswind taxiing, even the nosewheel-type airplane has some tendency to weathervane. The nosewheel linkage from the rudder pedals provides adequate steering control for safe and efficient ground handling, and normally, only rudder pressure is necessary to correct for a crosswind.

**TAXI CLEARANCES AT AIRPORTS WITH AN OPERATING CONTROL TOWER**

Approval must be obtained prior to moving an aircraft onto the movement area during the hours an air traffic control (ATC) tower is in operation. Also, a clearance must be obtained prior to taxiing on a
runway, taking off, or landing.

When an aircraft is cleared to taxi to an assigned runway, the absence of holding instructions authorizes the aircraft to cross all runways that the taxiway intersects, except the assigned takeoff runway. The pilot may not taxi onto or cross the assigned takeoff runway at any point.

At times, ATC may issue holding instructions or issue a specific taxi route. Anytime a pilot is unsure about a clearance; he or she should ask ATC for clarification. It is a good operating practice to always read back any clearance received by ATC. Pilots should always read back, in full, any clearance that includes a runway assignment or takeoff clearance. If operating at an unfamiliar airport, the pilot may request progressive taxi instructions from ATC.

Although ATC issues a taxi clearance, it is the pilot’s responsibility to avoid collision with other aircraft. Therefore, the pilot should always be alert and scan the area during taxi operations.

BEFORE TAKEOFF CHECK

The before takeoff check is the systematic procedure for making a check of the engine, controls, systems, instruments, and avionics prior to flight. Normally, it is performed after taxiing to a position near the takeoff end of the runway. Taxiing to that position usually allows sufficient time for the engine to warm up to at least minimum operating temperatures. This ensures adequate lubrication and internal engine clearances before being operated at high-power settings. Many engines require that the oil temperature reach a minimum value as stated in the AFM/POH before high power is applied.

Air-cooled engines generally are closely cowled and equipped with pressure baffles that direct the flow of air to the engine in sufficient quantities for cooling in flight. On the ground, however, much less air is forced through the cowling and around the baffling. Prolonged ground operations may cause cylinder overheating long before there is an indication of rising oil temperature. Cowl flaps, if available, should be set according to the AFM/POH.

Before beginning the before takeoff check, the airplane should be positioned clear of other aircraft. There should not be anything behind the airplane that might be damaged by the prop blast. To minimize overheating during engine runup, it is recommended that the airplane be headed as nearly as possible into the wind. After the airplane is properly positioned for the runup, it should be allowed to roll forward slightly so that the nosewheel or tailwheel will be aligned fore and aft.

During the engine runup, the surface under the airplane should be firm (a smooth, paved, or turf surface if possible) and free of debris. Otherwise, the propeller may pick up pebbles, dirt, mud, sand, or other loose objects and hurl them backwards. This damages the propeller and may damage the tail of the airplane. Small chips in the leading edge of the propeller form stress risers, or lines of concentrated high stress. These are highly undesirable and may lead to cracks and possible propeller blade failure.

While performing the engine runup, the pilot must divide attention inside and outside the airplane. If the parking brake slips, or if application of the toe brakes is inadequate for the amount of power applied, the airplane could move forward unnoticed if attention is fixed inside the airplane.

Each airplane has different features and equipment, and the before takeoff checklist provided by the airplane manufacturer or operator should be used to perform the runup.
AFTER-LANDING

During the after-landing roll, the airplane should be gradually slowed to normal taxi speed before turning off the landing runway. Any significant degree of turn at faster speeds could result in ground looping and subsequent damage to the airplane.

To give full attention to controlling the airplane during the landing roll, the after-landing check should be performed only after the airplane is brought to a complete stop clear of the active runway. There have been many cases of the pilot mistakenly grasping the wrong handle and retracting the landing gear, instead of the flaps, due to improper division of attention while the airplane was moving. However, this procedure may be modified if the manufacturer recommends that specific after-landing items be accomplished during landing rollout. For example, when performing a short-field landing, the manufacturer may recommend retracting the flaps on rollout to improve braking. In this situation, the pilot should make a positive identification of the flap control and retract the flaps.

Clear of the Runway Checks

Because of different features and equipment in various airplanes, the after-landing checklist provided by the manufacturer should be used. Some of the items may include:

- Hold brakes ON.
- Identify landing flaps control and retract flaps.
- Open engine cowl flaps (if equipped).
- Recheck and set propeller control (if equipped) to FULL INCREASE.
- Set trim tabs for takeoff.

Parking

Unless parking in a designated, supervised area, the pilot should select a location and heading which will prevent the propeller or jet blast of other airplanes from striking the airplane broadside. Whenever possible, the airplane should be parked headed into the existing or forecast wind. After stopping on the desired heading, the airplane should be allowed to roll straight ahead enough to straighten the nosewheel or tailwheel.

Engine Shutdown Check

Finally, the pilot should always use the procedures in the manufacturer’s checklist for shutting down the engine and securing the airplane. Some of the important items include:

- Set the parking brakes ON.
- Set throttle to IDLE or 1,000 RPM. If turbocharged, observe manufacturer’s spool down procedure.
- Turn ignition switch OFF then ON at idle to check for proper operation of switch in the OFF position.
- Set propeller control (if equipped) to FULL INCREASE.
- Turn electrical units and radios OFF.
- Set mixture control to IDLE CUTOFF.
- Turn ignition switch to OFF when engine stops.
- Turn master electrical switch to OFF.
- Install control lock.
POSTFLIGHT
A flight is never complete until the engine is shut down and the airplane is secured. A pilot should consider this an essential part of any flight.

Securing and Servicing
After engine shutdown and deplaning passengers, the pilot should accomplish a postflight inspection. This includes checking the general condition of the aircraft. For a departure, the oil should be checked and fuel added if required. If the aircraft is going to be inactive, it is a good operating practice to fill the tanks to the top to prevent water condensation from forming. When the flight is completed for the day, the aircraft should be hangared or tied down and the flight controls secured.
CHAPTER 3 - TAKEOFFS AND CLIMBS

INTRODUCTION

This chapter discusses safe operations during taxi, takeoff, and climbs for tricycle landing gear (nosewheel-type) aircraft under normal conditions and maximum takeoff performance. The takeoff and climb involves the movement of the airplane from its starting position on the runway to the point where a positive climb to a safe maneuvering altitude has been established. Since the takeoff requires both ground and inflight operation, the pilot must be able to use the controls during the transition from ground functions to inflight functions with maximum smoothness and coordination. Skill in these functions will improve the pilot's ability to control the airplane's direction of movement on and away from the runway.

TERMS AND DEFINITIONS

Although the takeoff and climb is one continuous maneuver, it will be divided into three separate steps for purposes of explanation: (1) the takeoff roll, (2) the lift-off, and (3) the initial climb after becoming airborne. [Figure 3-1]

- Takeoff Roll (ground roll)—the portion of the takeoff procedure during which the airplane is accelerated from a standstill to an airspeed that provides sufficient lift for it to become airborne.

- Lift-off (rotation)—the act of becoming airborne as a result of the wings lifting the airplane off the ground or the pilot rotating the nose up, increasing the angle of attack to start a climb.

- Initial Climb—begins when the airplane leaves the ground and a pitch attitude has been established to climb away from the takeoff area. Normally, it is considered complete when the airplane has reached a safe maneuvering altitude, or an en route climb has been established.

![Figure 3-1.—Normal takeoff and climb.](image-url)
PRIOR TO TAKEOFF

Before taxiing onto the runway or takeoff area, the pilot should ensure that the engine is operating properly and that all controls, including flaps and trim tabs, are set in accordance with the before takeoff checklist. In addition, the pilot must make certain that the approach and takeoff path is clear of other aircraft. At uncontrolled airports, pilots should announce their intentions on the common traffic advisory frequency (CTAF) assigned to that airport. When operating from an airport with an operating control tower, pilots must contact the tower operator and receive a takeoff clearance before taxiing onto the active runway.

It is not recommended to take off immediately behind another aircraft, particularly large, heavily loaded transport airplanes, because of the wake turbulence that is generated.

While taxiing onto the runway, the pilot can select ground reference points that are aligned with the runway direction as aids to maintaining directional control during the takeoff. These may be runway centerline markings, runway lighting, distant trees, towers, buildings, or mountain peaks.

NORMAL TAKEOFF

A normal takeoff is one in which the airplane is headed into the wind, or the wind is very light. Also, the takeoff surface is firm and of sufficient length to permit the airplane to gradually accelerate to normal lift-off and climb-out speed, and there are no obstructions along the takeoff path.

There are two reasons for making a takeoff as nearly into the wind as possible. First, the airplane’s speed while on the ground is much less than if the takeoff were made down wind, thus reducing wear and stress on the landing gear. Second, a shorter ground roll and therefore much less runway length is required to develop the minimum lift necessary for takeoff and climb. Since the airplane depends on airspeed in order to fly, a headwind provides some of that airspeed, even with the airplane motionless, from the wind flowing over the wings.

Takeoff Roll

After taxiing onto the runway, the airplane should be carefully aligned with the intended takeoff direction, and the nosewheel positioned straight, or centered. After releasing the brakes, the throttle should be advanced smoothly and continuously to takeoff power. An abrupt application of power may cause the airplane to yaw sharply to the left because of the torque effects of the engine and propeller. This will be most apparent in high horsepower engines. As the airplane starts to roll forward, the pilot should assure both feet are on the rudder pedals so that the toes or balls of the feet are on the rudder portions, not on the brake portions. [Figure 3-2] Engine instruments should be monitored during the takeoff roll for any malfunctions.

![Figure 3-2.—Typical rudder and brake pedal.](image)

In nosewheel-type airplanes, pressures on the elevator control are not necessary beyond those
needed to steady it. Applying unnecessary pressure will only aggravate the takeoff and prevent the pilot from recognizing when elevator control pressure is actually needed to establish the takeoff attitude.

As speed is gained, the elevator control will tend to assume a neutral position if the airplane is correctly trimmed. At the same time, directional control should be maintained with smooth, prompt, positive rudder corrections throughout the takeoff roll. The effects of engine torque and P-factor at the initial speeds tend to pull the nose to the left. The pilot must use whatever rudder pressure and aileron needed to correct for these effects or for existing wind conditions to keep the nose of the airplane headed straight down the runway. The use of brakes for steering purposes should be avoided, since this will cause slower acceleration of the airplane’s speed, lengthen the takeoff distance, and possibly result in severe swerving.

While the speed of the takeoff roll increases, more and more pressure will be felt on the flight controls, particularly the elevators and rudder. Since the tail surfaces (except “T” tails) receive the full effect of the propeller slipstream, they become effective first. As the speed continues to increase, all of the flight controls will gradually become effective enough to maneuver the airplane about its three axes. It is at this point, in the taxi to flight transition, that the airplane is being flown more than taxied. As this occurs, progressively smaller rudder deflections are needed to maintain direction.

The feel of resistance to the movement of the controls and as the airplane’s reaction to such movements is the only real indicators of the degree of control attained. This feel of resistance is not a measure of the airplane’s speed, but rather of its controllability. To determine the degree of controllability, the pilot must be conscious of the reaction of the airplane to the control pressures and immediately adjust the pressures as needed to control the airplane.

**Lift-off**

Since a good takeoff depends on the proper takeoff attitude, it is important to know how this attitude appears and how it is attained. The ideal takeoff attitude requires only minimum pitch adjustments shortly after the airplane lifts off to attain the speed for the best rate of climb speed (V\textsubscript{y}). [Figure 3-3]

![Figure 3-3.—Initial roll and takeoff attitude.](image)

Each type of airplane has a best pitch attitude for normal lift-off; however, varying conditions may make a difference in the required takeoff technique. A rough field, a smooth field, a hard surface runway, or a short or soft, muddy field, all call for a slightly different technique, as will smooth air in contrast to a strong, gusty wind. The different techniques for those other-than-normal conditions are discussed later in this chapter.
When all the flight controls become effective during the takeoff roll in a nosewheel-type airplane, back-elevator pressure should be gradually applied to raise the nosewheel slightly off the runway, thus establishing the takeoff or lift-off attitude. This is often referred to as “rotating.” At this point, the position of the nose in relation to the horizon should be noted, then back elevator pressure applied as necessary to hold this attitude. The wings are to be kept level by applying aileron pressure as necessary.

The airplane is allowed to fly off the ground while in this normal takeoff attitude. Forcing it into the air by applying excessive back-elevator pressure would only result in an excessively high pitch attitude and may delay the takeoff. As discussed earlier, excessive and rapid changes in pitch attitude result in proportionate changes in the effects of torque, thus making the airplane more difficult to control.

Although the airplane can be forced into the air, this is considered an unsafe practice and should be avoided under normal circumstances. If the airplane is forced to leave the ground by using too much back-elevator pressure before adequate flying speed is attained, the wing’s angle of attack may be excessive, causing the airplane to settle back to the runway or even to stall. On the other hand, if sufficient back-elevator pressure is not held to maintain the correct takeoff attitude after becoming airborne, or the nose is allowed to lower excessively, the airplane may also settle back to the runway. This would occur because the angle of attack is decreased and lift diminished to the degree where it will not support the airplane. It is important, then, to hold the correct attitude constant after rotation or lift-off.

Even as the airplane leaves the ground, the pilot must continue to be concerned with maintaining the wings in a level attitude, as well as holding the proper pitch attitude. During takeoffs in a strong, gusty wind, it is advisable that an extra margin of speed be obtained before the airplane is allowed to leave the ground. A takeoff at the normal takeoff speed may result in a lack of positive control, or a stall, when the airplane encounters a sudden lull in strong, gusty wind, or other turbulent air currents. In this case, the pilot should allow the airplane to stay on the ground longer to attain more speed; then make a smooth, positive rotation to leave the ground.

**Initial Climb**

Upon lift-off, the airplane should be flying at approximately the pitch attitude that will allow it to accelerate to Vy. This is the speed at which the airplane will gain the most altitude in the shortest period of time.

If the airplane has been properly trimmed, some back-elevator pressure may be required to hold this attitude until the proper climb speed is established. On the other hand, relaxation of any back-elevator pressure before this time may result in the airplane settling, even to the extent that it contacts the runway.

The airplane will pick up speed rapidly after it becomes airborne. Once a positive rate of climb is established, the flaps and landing gear can be retracted (if equipped).

It is recommended that takeoff power be maintained until reaching an altitude of at least 500 feet above the surrounding terrain or obstacles. The combination of Vy and takeoff power assures the maximum altitude gained in a minimum amount of time. This gives the pilot more altitude from which the airplane can be safely maneuvered in case of an engine failure or other emergency.

Since the power on the initial climb is fixed at the takeoff power setting, the airspeed must be
controlled by making slight pitch adjustments using the elevators. However, the pilot should not stare at the airspeed indicator when making these slight pitch changes, but should, instead, watch the attitude of the airplane in relation to the horizon. It is better to first make the necessary pitch change and hold the new attitude momentarily, and then glance at the airspeed indicator as a check to see if the new attitude is correct. Due to inertia, the airplane will not accelerate or decelerate immediately as the pitch is changed. It takes a little time for the airspeed to change. If the pitch attitude has been over or under corrected, the airspeed indicator will show a speed that is more or less than that desired. When this occurs, the cross-checking and appropriate pitch-changing process must be repeated until the desired climbing attitude is established.

When the correct pitch attitude has been attained, it should be held constant while cross-checking it against the horizon and other outside visual references. The airspeed indicator should be used only as a check to determine if the attitude is correct.

After the recommended climb airspeed has been established, and a safe maneuvering altitude has been reached, the power should be adjusted to the recommended climb setting and the airplane trimmed to relieve the control pressures. This will make it much easier to hold a constant attitude and airspeed.

During initial climb, it is important that the takeoff path remain aligned with the runway to avoid the hazards of drifting into obstructions, or the path of another aircraft that may be taking off from a parallel runway.

CROSSWIND TAKEOFF

While it is usually preferable to take off directly into the wind whenever possible or practical, there will be many instances when circumstances or judgment will indicate otherwise. Therefore, the pilot must be familiar with the principles and techniques involved in crosswind takeoffs, as well as those for normal takeoffs. A crosswind will affect the airplane during takeoff much as it does in taxiing. With this in mind, it can be seen that the technique for crosswind correction during takeoffs closely parallels the crosswind correction techniques used in taxiing, previously explained in this handbook.

Takeoff Roll

The technique used during the initial takeoff roll in a crosswind is generally the same as used in a normal takeoff, except that the aileron control must be held INTO the crosswind. This raises the aileron on the upwind wing to impose a downward force on the wing to counteract the lifting force of the crosswind and prevents the wing from rising.

As the airplane is taxied into takeoff position, it is essential that the windsock and other wind direction indicators be checked so that the presence of a crosswind may be recognized and anticipated. If a crosswind is indicated, FULL aileron should be held into the wind as the takeoff roll is started. This control position should be maintained while the airplane is accelerating and until the ailerons start becoming sufficiently effective for maneuvering the airplane about its longitudinal axis.

With the aileron held into the wind, the takeoff path must be held straight with the rudder. [Figure 3-4] Normally, this will require applying downwind rudder pressure, since on the ground the airplane will tend to weathervane into the wind. When takeoff power is applied, torque or P-factor that yaws the airplane to the left may be sufficient to counteract the weathervaning tendency caused by a crosswind from the right. On the other hand, it may also aggravate the tendency to swerve left when the wind is from the left. In any case, whatever rudder pressure is required to keep the
airplane rolling straight down the runway should be applied.

As the forward speed of the airplane increases and the crosswind becomes more and more of a relative headwind, the mechanical holding of full aileron into the wind should be reduced. It is when increasing pressure is being felt on the aileron control that the ailerons are becoming more effective. As the aileron’s effectiveness increases and the crosswind component of the relative wind becomes less effective, it will be necessary to gradually reduce the aileron pressure. The crosswind component effect does not completely vanish, so some aileron pressure will have to be maintained throughout the takeoff roll to keep the crosswind from raising the upwind wing. If the upwind wing rises, thus exposing more surface to the crosswind, a “skipping” action may result. [Figure 3-5] This is usually indicated by a series of very small bounces, caused by the airplane attempting to fly and then settling back onto the runway. During these bounces, the crosswind also tends to move the airplane sideways, and these bounces will develop into side skipping. This side skipping imposes severe side stresses on the landing gear and could result in structural failure.

It is important during a crosswind takeoff roll, to hold sufficient aileron into the wind not only to keep the upwind wing from rising but to hold that wing down so that the airplane will, immediately after lift-off, be slipping into the wind enough to counteract drift.

Figure 3-4.—Crosswind takeoff roll and climb.

Figure 3-5.—Crosswind effect
Lift-Off

As the nosewheel is being raised off the runway, the holding of aileron control into the wind may result in the downwind wing rising and the downwind main wheel lifting off the runway first, with the remainder of the takeoff roll being made on that one main wheel. This is acceptable and is preferable to side skipping.

If a significant crosswind exists, the main wheels should be held on the ground slightly longer than in a normal takeoff so that a smooth but very definite lift-off can be made. This procedure will allow the airplane to leave the ground under more positive control so that it will definitely remain airborne while the proper amount of wind correction is being established. More importantly, this procedure will avoid imposing excessive side loads on the landing gear and prevent possible damage that would result from the airplane settling back to the runway while drifting.

As both main wheels leave the runway and ground friction no longer resists drifting, the airplane will be slowly carried sideways with the wind unless adequate drift correction is maintained by the pilot. Therefore it is important to establish and maintain the proper amount of crosswind correction prior to lift-off by applying aileron pressure toward the wind to keep the upwind wing from rising and applying rudder pressure as needed to prevent weathervaning.

Initial Climb

If proper crosswind correction is being applied, as soon as the airplane is airborne, it will be slipping into the wind sufficiently to counteract the drifting effect of the wind. [Figure 3-6] This slipping should be continued until the airplane has a positive rate of climb. At that time, the airplane should be headed toward the wind to establish just enough wind correction angle to counteract the wind and then the wings rolled level. The climb with this wind correction angle should be continued to follow a ground track aligned with the runway direction. The remainder of the climb technique is the same used for normal takeoffs and climbs.

SHORT-FIELD TAKEOFF AND CLIMB

Takeoffs and climbs from fields where the takeoff area is short or the available takeoff area is restricted by obstructions requires that the pilot operate the airplane at the limit of its takeoff performance capabilities. To depart from such an area safely, the pilot must exercise positive and precise control of airplane attitude and airspeed so that takeoff and climb performance results in the shortest ground roll and the steepest angle of climb. [Figure 3-7]
The achieved result should be consistent with the performance section of the JAA-approved Airplane Flight Manual (AFM) and/or Pilot's Operating Handbook (POH). In all cases, the power setting, flap setting, airspeed, and procedures prescribed by the airplane's manufacturer should be followed.

In order to accomplish a maximum performance takeoff safely, the pilot must have adequate knowledge in the use and effectiveness of the best angle-of-climb speed (VX) and the best rate-of-climb speed (VY) for the specific make and model of airplane being flown.

The speed for VX is that which will result in the greatest gain in altitude for a given distance over the ground. It is usually slightly less than VY which provides the greatest gain in altitude per unit of time. The specific speeds to be used for a given airplane are stated in the approved AFM/POH.

Taking off from a short field requires the takeoff to be started from the very beginning of the takeoff area. At the field threshold, the airplane is aligned with the intended takeoff path. If the airplane manufacturer recommends the use of flaps, they should be extended the proper amount before starting the takeoff roll. This permits the pilot to give full attention to the proper technique and the airplane's performance throughout the takeoff.

Takeoff power should be applied smoothly and continuously to accelerate the airplane as rapidly as possible; the airplane should be allowed to roll with its full weight on the main wheels and
accelerated to the lift-off speed. As the takeoff roll progresses, the airplane’s pitch attitude and angle of attack should be adjusted to that which results in the minimum amount of drag and the quickest acceleration. In nosewheel-type airplanes, this will involve little use of the elevator control, since the airplane is already in a low drag attitude.

The airplane should be smoothly and firmly lifted off, or rotated, by applying back-elevator pressure as approaching \( V_X \). Since the airplane will accelerate more rapidly after lift-off, additional back-elevator pressure becomes necessary to hold a constant airspeed. After becoming airborne, a wings level climb should be maintained at \( V_X \) until the obstacles have been cleared or, if no obstacles are involved, until an altitude of at least 50 feet above the takeoff surface is attained. Thereafter, the pitch attitude may be lowered slightly, and the climb continued at \( V_Y \) until reaching a safe maneuvering altitude. Remember that an attempt to pull the airplane off the ground prematurely, or to climb too steeply, may cause the airplane to settle back to the runway or into the obstacles.

On short-field takeoffs, the flaps and landing gear should remain in takeoff position until clear of obstacles (or as recommended by the manufacturer) and \( V_Y \) has been established. It is generally unwise for the pilot to be looking in the cockpit or reaching for flap and landing gear controls until obstacle clearance is assured. When the \( V_Y \) has stabilized, the gear (if equipped) and then the flaps should be retracted. It is usually advisable to raise the flaps in increments to avoid sudden loss of lift and settling of the airplane. Next, reduce the power to the normal climb setting or as recommended by the aircraft manufacturer.

**SOFT-FIELD TAKEOFF AND CLimb**

Takeoffs and climbs from soft fields require the use of operational techniques for getting the airplane airborne as quickly as possible to eliminate the drag caused by tall grass, soft sand, mud, and snow, and may or may not require climbing over an obstacle. These same techniques are also useful on a rough field where it is advisable to get the airplane off the ground as soon as possible to avoid damaging the landing gear.

Soft surfaces or long, wet grass usually reduces the airplane’s acceleration during the takeoff roll so much that adequate takeoff speed might not be attained if normal takeoff techniques were employed.

The correct takeoff procedure at soft fields is quite different from that appropriate for short fields with firm, smooth surfaces. To minimize the hazards associated with takeoffs from soft or rough fields, support of the airplane’s weight must be transferred as rapidly as possible from the wheels to the wings as the takeoff roll proceeds. Establishing and maintaining a relatively high angle of attack or nose-high pitch attitude as early as possible does this. Wing flaps may be lowered prior to starting the takeoff (if recommended by the manufacturer) to provide additional lift and to transfer the airplane’s weight from the wheels to the wings as early as possible.

![Figure 3-8.—Soft-field takeoff.](image-url)

Stopping on a soft surface, such as mud or snow, might bog the airplane down; therefore, it should
be kept in continuous motion with sufficient power while lining up for the takeoff roll. As the airplane is aligned with the takeoff path, takeoff power is applied smoothly and as rapidly as the powerplant will accept it without faltering. As the airplane accelerates, enough back-elevator pressure should be applied to establish a positive angle of attack and to reduce the weight supported by the nosewheel.

When the airplane is held at a nose-high attitude throughout the takeoff run, the wings will, as speed increases and lift develops, progressively relieve the wheels of more and more of the airplane's weight, thereby minimizing the drag caused by surface irregularities or adhesion. If this attitude is accurately maintained, the airplane will virtually fly itself off the ground. It may even become airborne at airspeed slower than a safe climb speed because of ground effect. This phenomenon produces an interim gain in lift during flight at very low altitude due to the effect the ground has on the flow pattern of the air passing along the wing. Ground effect is discussed in the following section. [Figure 3-8]

After becoming airborne, the nose should be lowered very gently with the wheels clear of the surface to allow the airplane to accelerate to \( V_Y \) or \( V_X \) if obstacles must be cleared. Extreme care must be exercised immediately after the airplane becomes airborne and while it accelerates, to avoid settling back onto the surface. An attempt to climb prematurely or too steeply may cause the airplane to settle back to the surface as a result of losing the benefit of ground effect. Therefore, it is recommended the airplane remain in ground effect until at least \( V_X \) is reached.

After a positive rate of climb is established, and the airplane has accelerated to \( V_Y \), retract the landing gear and flaps, if equipped. If departing from an airstrip with wet snow or slush on the takeoff surface, the gear should not be retracted immediately. This allows for any wet snow or slush to be air-dried. In the event an obstacle must be cleared after a soft-field takeoff, the climb-out is performed at \( V_X \) until the obstacle has been cleared. After reaching this point, the pitch attitude is adjusted to \( V_Y \) and the gear and flaps are retracted. The power may then be reduced to the normal climb setting.

**Ground Effect**

Ground effect is a condition of improved performance encountered when the aircraft is operating near the ground. A change occurs in the three-dimensional flow pattern around the airplane because the vertical component of the airflow around the wing is restricted by the ground surface. This alters the wing’s upwash, downwash, and wingtip vortices. [Figure 3-9] While the aerodynamic characteristics of the tail surfaces and the fuselage are altered by ground effects, the principal effects due to proximity of the ground are the changes in the aerodynamic characteristics of the wing. As the wing encounters ground effect and is maintained at a constant lift coefficient, there is a reduction in the upwash, downwash, and the wingtip vortices.

In order for ground effect to be of significant magnitude, the wing must be quite close to the ground. One of the direct results of ground effect is the variation of induced drag with wing height above the ground at a constant lift coefficient. When the wing is at a height equal to its span, the reduction in induced drag is only 1.4 percent. However, when the wing is at a height equal to one-fourth its span, the reduction in induced drag is 23.5 percent and, when the wing is at a height equal to one-tenth its span, the reduction in induced drag is 47.6 percent. Thus, a large reduction in induced drag will take place only when the wing is very close to the ground. Because of this variation, ground effect is most usually recognized during the lift-off for takeoff or just prior to touchdown when landing.
During the takeoff phase of flight, ground effect produces some important relationships. The airplane leaving ground effect after takeoff encounters just the reverse of the airplane entering ground effect during landing; i.e., the airplane leaving ground effect will:

- require an increase in the angle of attack to maintain the same lift coefficient;
- experience an increase in induced drag and thrust required;
- experience a decrease in stability and a noseup change in moment; and
- produce a reduction in static source pressure and increase in indicated airspeed.

These general effects should point out the possible danger in attempting takeoff prior to achieving the recommended lift-off speed. Due to the reduced drag in ground effect, the airplane may seem capable of takeoff well below the recommended speed. However, as the airplane rises out of ground effect with a lower-than-normal lift-off speed, the greater induced drag may result in very marginal initial climb performance.

In extreme conditions, such as high gross weight, high density altitude, and high temperature, lower-than-normal lift-off speed may permit the airplane to become airborne, but incapable of flying out of ground effect. In this case, the airplane may become airborne and then settle back to the runway. It is important not to force the airplane to become airborne before the recommended takeoff speed. The recommended takeoff speed is necessary to provide adequate initial climb performance. For this reason, it is imperative that a definite climb be established before retracting the landing gear or flaps.

Figure 3-9.—*Ground effect.*

**REJECTED TAKEOFF**

Emergency or abnormal situations can occur during a takeoff that will require a pilot to reject the takeoff while still on the runway. Circumstances such as a malfunctioning powerplant, inadequate acceleration, runway incursion, or air traffic conflict may be reasons for a rejected takeoff.
In the event a takeoff is rejected, the power should be reduced to idle and maximum braking applied while maintaining directional control. If it is necessary to shut down the engine due to a fire, the mixture control should be brought to the idle cutoff position and the magnetos turned off. In all cases, the manufacturer’s emergency procedure should be followed.

**NOISE ABATEMENT**

Airplane noise problems have become a major concern at many airports throughout the country. Many local communities have pressured airports into developing specific operational procedures that will help limit airplane noise while operating over nearby areas. For years now, the JAA, airport managers, airplane operators, pilots, and special interest groups have been working together to minimize airplane noise for nearby sensitive areas. As a result, noise abatement procedures have been developed for many of these airports that include standardized profiles and procedures to achieve these lower noise goals.

Airports that have noise abatement procedures provide information to pilots, operators, air carriers, air traffic facilities, and other special groups that are applicable to their airport. These procedures are available to the aviation community by various means. Most of this information comes from; the Airport/Facility Directory, local and regional publications, printed handouts, operator bulletin boards, safety briefings, and local air traffic facilities. At airports that use noise abatement procedures, reminder signs may be installed at the taxiway hold positions for applicable runways. These are to remind pilots to use and comply with noise abatement procedures on departure. If a pilot is not familiar with these procedures he should ask the tower or air traffic facility for the recommended procedures. In any case, pilots should be considerate of the surrounding community while operating their airplane to and from such an airport. This includes operating as quietly, yet safely as possible.
CHAPTER 4 - BASIC FLIGHT MANEUVERS

INTRODUCTION

This chapter discusses integrated flight instruction, attitude flying concepts, and the basic flight maneuvers that all flying tasks and techniques are based on. When learning to fly, the basic fundamentals and maneuvers must be mastered before the more advanced maneuvers can be learned.

Basic flight maneuvers include the four fundamentals of flight: straight and level, turns, climbs, and descents. Controlled flight consists of either one, or a combination of these basic maneuvers. Proper control of an airplane is the result of the pilot knowing when and how to make pitch, bank, and power changes.

In flight training, control of the airplane is a matter of fixing the relationship of the nose and wingtips of the airplane to a specific position in relation to the horizon. As basic flying skills are developed through training and experience, the pilot will acquire an awareness of these references.

INTEGRATED FLIGHT INSTRUCTION

When introducing basic flight maneuvers to a beginning pilot, it is recommended that the integrated flight instruction method be used. When this type of instruction is used, training in the control of an airplane by outside visual references is integrated with instruction in the use of flight instruments. When beginning pilots use this technique, they achieve a more precise and competent overall piloting ability.

The use of this type of training does not, and is not intended to, prepare pilots for flight in instrument meteorological conditions (IMC). It does, however, provide basic instrument skills to be used in an emergency. This type of instruction also provides an excellent foundation for advanced training for those seeking to obtain an instrument rating.

When using the flight instruments, the responsibility to see and avoid other aircraft becomes more demanding.

ATTITUDE FLYING

Airplane control is composed of four components: pitch, bank, power control, and trim.

[Figure 4-1]

- Pitch control is the control of the airplane about the lateral axis by using the elevator to raise or lower the nose.
- Bank control is control of the airplane about the longitudinal axis by use of the ailerons to attain a desired angle of bank.
- Power control is the control of power by use of the throttle to establish or maintain desired performance.
- Trim control assists in holding an airplane in steady flight. The airplane should be trimmed by
first applying control pressure to establish the desired attitude, and then adjusting the trim so that the airplane will maintain the attitude without control pressure in hands-off flight.

**Figure 4-1.—Pitch and bank control.**

The following instruments are used as references for control of the airplane are attitude indicator, heading indicator, altimeter, airspeed indicator, vertical speed indicator (VSI), and turn coordinator.

- The attitude indicator shows both the pitch and bank attitude of the airplane.
- The heading indicator shows the airplane’s direction of flight.
- The altimeter indicator shows the airplane’s altitude and the need for a pitch change.
- The airspeed indicator shows the results of power and/or pitch changes by the airplane’s speed.
- The VSI shows the rate of climb or descent.
- The turn coordinator shows the direction, rate, and quality of the turn.

**STRAIGHT-AND-LEVEL FLIGHT**

Straight-and-level flight is a condition of flight in which a constant heading and altitude are maintained. It is accomplished by making small corrections for slight turns, descents, and climbs.

During straight-and-level flight, the pilot selects two or more outside visual reference points directly ahead of the airplane, such as towns, lakes, or distant clouds, and keeps the airplane’s nose headed toward those objects. When using these references, a check of the heading indicator should be made frequently to determine that the airplane is maintaining flight in the desired direction.

Straight-and-level flight may also be accomplished by visually checking the relationship of the airplane’s wingtips with the horizon. Both wingtips should be an equal distance above or below the horizon (depending on whether the airplane is a high-wing or low-wing type). Any necessary adjustments to bank should be made with the ailerons.

Observing the wingtips helps divert the pilot’s attention from the airplane’s nose and expands the area of visual scanning. [Figure 4-2]
The pitch attitude for level flight (constant altitude) is obtained by selecting some portion of the airplane’s nose as a reference point, and then keeping that point in a fixed position relative to the horizon. That position should be cross-checked against the altimeter to determine whether or not the pitch attitude is correct. If altitude is being gained or lost, the nose attitude should be readjusted in relation to the horizon and then the altimeter rechecked to determine if altitude is now being maintained. The pitch information obtained from the attitude indicator will show the position of the nose relative to the horizon and will indicate the necessary corrections to return to level flight. [Figure 4-3]

For all practical purposes, the airspeed will remain constant in straight-and-level flight with a constant power setting. Practicing airspeed changes by increasing or decreasing the power will provide an excellent means of developing proficiency in maintaining straight-and-level flight at various speeds. Significant changes in airspeed will require changes in pitch attitude and trim to maintain altitude. Pronounced changes in pitch attitude and trim will also be necessary as the flaps and landing gear are extended or retracted.

**TURNS**

A turn is a basic flight maneuver used to change or return to a desired heading. It involves close coordination of all three flight controls: aileron, rudder, and elevator. Since turns are a part of most other flight maneuvers, it is important to thoroughly understand the factors involved.

For purposes of this discussion, turns are divided into three classes: shallow turns, medium turns, and steep turns. [Figure 4-4]

- Shallow turns are those in which the bank (less than approximately 20°) is so shallow that the inherent lateral stability of the airplane is acting to level the wings unless some aileron is applied to maintain the bank.
- Medium turns are those resulting from a degree of bank (approximately 20° to 45°) at which the airplane remains at a constant bank.
- Steep turns are those resulting from a degree of bank (45° or more) at which the “overbanking tendency” of an airplane overcomes stability, and the bank increases unless
aileron is applied to prevent it.

**Figure 4-3.**—Outside and instrument references.

**Figure 4-4.**—Shallow, medium, and steep turns.
Changing the direction of the wing’s lift toward one side or the other causes the airplane to be pulled in that direction. Applying coordinated aileron and rudder to bank the airplane in the direction of the desired turn does this. [Figure 4-5]

![Figure 4-5.—Unbalanced lift results in banking.](image)

When an airplane is flying straight and level, the total lift is acting perpendicular to the wings and to the Earth. As the airplane is banked into a turn, the lift then becomes the resultant of two components. One, the vertical lift component, continues to act perpendicular to the Earth and opposes gravity. Second, the horizontal lift component (centripetal) acts parallel to the Earth’s surface and opposes inertia (apparent centrifugal force). These two lift components act at right angles to each other, causing the resultant total lifting force to act perpendicular to the banked wing of the airplane. It is the horizontal lift component that actually turns the airplane—not the rudder. [Figure 4-6]

When applying aileron to bank the airplane, the lowered aileron (on the rising wing) produces a greater drag than the raised aileron (on the lowering wing). This increased aileron yaws the airplane toward the rising wing, or opposite to the direction of turn. To counteract this adverse yawing moment, rudder pressure must be applied simultaneously with aileron in the desired direction of turn. This action is required to produce a coordinated turn.
After the bank has been established in a medium banked turn, all pressure applied to the aileron may be relaxed. The airplane will remain at the selected bank with no further tendency to yaw since there is no longer a deflection of the ailerons. As a result, pressure may also be relaxed on the rudder pedals, and the rudder allowed to streamline itself with the direction of the slipstream. Rudder pressure maintained after the turn is established will cause the airplane to skid to the outside of the turn. If a definite effort is made to center the rudder rather than let it streamline itself to the turn, it is probable that some opposite rudder pressure will be exerted inadvertently. This will force the airplane to yaw opposite its turning path, causing the airplane to slip to the inside of the turn. The ball in the turn-and-slip indicator will be displaced off-center whenever the airplane is skidding or slipping sideways. In proper coordinated flight, there is no skidding or slipping. [Figure 4-7]

In all constant altitudes, constant airspeed turns, it is necessary to increase the angle of attack of the wing when rolling into the turn by applying up elevator. This is required because the total lift must be equal to the vertical component of lift plus the horizontal lift component.

To stop the turn, the wings are returned to level flight by the use of the ailerons and rudder applied in the opposite direction. To understand the relationship between airspeed, bank, and radius of turn, it should be noted that the rate of turn at any given true airspeed depends on the horizontal lift component. The horizontal lift component varies in proportion to the amount of bank. Therefore, the rate of turn at a given true airspeed increases as the angle of bank is increased. On the other hand, when a turn is made at a higher true airspeed at a given bank angle, the inertia is greater and the horizontal lift component required for the turn is greater, causing the turning rate to become slower. Therefore, at a given angle of bank, a higher true airspeed will make the radius of turn larger because the airplane will be turning at a slower rate.
When changing from a shallow bank to a medium bank, the airspeed of the wings on the outside of the turn increases in relation to the inside wing as the radius of turn decreases. The additional lift developed because of this increase in speed of the wing balances the inherent lateral stability of the airplane. At any given airspeed, aileron pressure is not required to maintain the bank. If the bank is allowed to increase from a medium to a steep bank, the radius of turn decreases further. The lift of the outside wing causes the bank to steepen and opposite aileron is necessary to keep the bank constant.

As the radius of the turn becomes smaller, a significant difference develops between the speed of the inside wing and the speed of the outside wing. The wing on the outside of the turn travels a longer circuit than the inside wing, yet both complete their respective circuits in the same length of time. Therefore, the outside wing travels faster than the inside wing, and as a result, it develops more lift. This creates an overbanking tendency that must be controlled by the use of the ailerons. Because the outboard wing is developing more lift, it also has more induced drag. This causes a slight slip during steep turns that must be corrected by use of the rudder. [Figure 4-8]

Sometimes during early training in steep turns, the nose may be allowed to get excessively low resulting in a significant loss in altitude. To recover, the pilot should first reduce the angle of bank with coordinated use of the rudder and aileron, then raise the nose of the airplane to level flight with the elevator. If recovery from an excessively nose-low steep bank condition is attempted by use of the elevator only, it will cause a steepening of the bank and could result in overstressing the airplane. Normally, small corrections for pitch during steep turns are accomplished with the elevator, and the bank is held constant with the ailerons.

Figure 4-8.—Overbanking tendency during a steep turn.

To establish the desired angle of bank, the pilot should use outside visual reference points, as well as the bank indicator on the attitude indicator.

The best outside reference for establishing the degree of bank is the angle formed between the top
of the engine cowling in relation to the horizon. Since on most light airplanes the engine cowling is fairly flat, its horizontal angle to the horizon will give some indication of the approximate degree of bank. Also, information obtained from the attitude indicator will show the angle of the wing in relation to the horizon.

The pilot’s posture while seated in the airplane is very important, particularly during turns. It will affect the interpretation of outside visual references. At the beginning, the student may lean away from the turn in an attempt to remain upright in relation to the ground rather than ride with the airplane. This should be corrected immediately if the student is to properly learn to use visual references. [Figure 4-9]

Figure 4-9.—Wrong and right posture while seated in the airplane.

Parallax error is common among students and experienced pilots. This error is a characteristic of airplanes that have side-by-side seats because the pilot is seated to one side of the longitudinal axis about which the airplane rolls. This makes the nose appear to rise when making a left turn and to descend when making right turns.

Beginning students should not use large aileron and rudder applications because this produces a rapid roll rate and allows little time for corrections before the desired bank is reached. Slower (small control displacement) roll rates provide more time to make necessary pitch and bank corrections. As soon as the airplane rolls from the wings-level attitude, the nose should also start to move along the horizon, increasing its rate of travel proportionately as the bank is increased.

The following variations provide excellent guides:

- If the nose starts to move before the bank starts, rudder is being applied too soon.
- If the bank starts before the nose starts turning, or the nose moves in the opposite direction, the rudder is being applied too late.
- If the nose moves up or down when entering a bank, excessive or insufficient up-elevator is being applied.

As the desired angle of bank is established, aileron and rudder pressures should be relaxed. This will stop the bank from increasing because the aileron and rudder control surfaces will be neutral in their streamlined position. The up-elevator pressure should not be relaxed, but should be held constant to
maintain a constant altitude. Throughout the turn the pilot should cross-check the airspeed indicator, and if the airspeed has decreased more than 5 knots, additional power should be used. The cross-check should also include outside references, altimeter, and VSI, which can help determine whether or not the pitch attitude is correct. If gaining or losing altitude, the pitch attitude should be adjusted in relation to the horizon, and then the altimeter and VSI rechecked to determine if altitude is being maintained.

During all turns, the ailerons, rudder, and elevator are used to correct minor variations in pitch and bank just as they are in straight-and-level flight.

The rollout from a turn is similar to the roll-in except the flight controls are applied in the opposite direction. Aileron and rudder are applied in the direction of the rollout or toward the high wing. As the angle of bank decreases, the elevator pressure should be relaxed as necessary to maintain altitude.

Since the airplane will continue turning as long as there is any bank, the rollout must be started before reaching the desired heading. The amount of lead required to rollout on the desired heading will depend on the degree of bank used in the turn. Normally, the lead is one half the degrees of bank. For example, if the bank is 30°, lead the rollout by 15°. As the wings become level, the control pressures should be smoothly relaxed so that the controls are neutralized as the airplane returns to straight-and-level flight. As the rollout is being completed, attention should be given to outside visual references, as well as the attitude and heading indicators to determine that the wings are being leveled and the turn stopped.

CLIMBS

Climbs and climbing turns are basic flight maneuvers used to gain altitude. When an airplane enters a climb, it changes its flightpath from level flight to an inclined plane or climb attitude. Weight for the first time is no longer acting in a direction perpendicular to the flightpath, but now acts in a rearward direction. This causes the total drag to increase requiring an increase in thrust (power) to balance the forces. An airplane can only sustain a climb angle when there is sufficient thrust to offset increased drag; therefore, climb is limited by the thrust available.

A normal climb is made at a constant-pitch attitude and airspeed using the manufacturer’s recommended climb power setting.

Figure 4-10.—Thrust and drag during a climb.
Like other maneuvers, climbs should be performed using both flight instruments and outside visual references. The normal climb speed that is recommended by the manufacturer should be used; this is usually the airplane’s best rate-of-climb speed (VY). Manufacturers may also recommend a cruise climb speed that is usually higher than VY. A cruise climb provides a slightly less rate of climb, but a significant increase in speed. It also provides for better engine cooling and increased flight visibility over the nose. [Figure 4-11]

![Figure 4-11.—Outside and instrument references for a climb.](image)

As a climb is started, the airspeed will gradually diminish. This reduction in airspeed is gradual because of the initial momentum of the airplane. The thrust required to maintain straight-and-level flight at a given airspeed is not sufficient to maintain the same airspeed in a climb. Climbing flight requires more power than flying level because of the increased drag caused by gravity acting rearward. Therefore, power must be advanced to a higher-power setting to offset the increased drag.

The propeller effects at climb power are a primary factor. This is because airspeed is significantly slower than at cruising speed, and the airplane’s angle of attack is significantly greater. Under these conditions, torque and asymmetrical loading of the propeller will cause the airplane to roll and yaw to the left. To counteract this, the right rudder must be used. During the early practice of climbs and climbing turns, this may make coordination of the controls seem awkward (left climbing turn holding right rudder), but after a little practice this correction for propeller effects will become instinctive.

Trim is also a very important consideration during a climb. After the climb has been established, the
airplane should be trimmed to relieve all pressures from the flight controls. If changes are made in the pitch attitude, power, or airspeed, the airplane should be retrimmed in order to relieve control pressures.

When performing a climb, the power should be advanced to the climb power recommended by the manufacturer. If the airplane is equipped with a controllable-pitch propeller, it will have not only an engine tachometer, but also a manifold pressure gauge. Normally, the flaps and landing gear (if retractable) should be in the retracted position to reduce drag.

As the airplane gains altitude during a climb, the manifold pressure gauge (if equipped) will indicate a loss in manifold pressure (power). This is because the same volume of air going into the engine’s induction system gradually decreases in density as altitude increases. When the volume of air in the manifold decreases, it causes a loss of power. This will occur at the rate of approximately 1-inch of manifold pressure for each 1,000-foot gain in altitude. During prolonged climbs, the throttle must be continually advanced, if constant power is to be maintained.

To enter the climb, simultaneously advance the throttle and apply back-elevator pressure to raise the nose of the airplane to the proper position in relation to the horizon. As power is increased, the airplane’s nose will rise due to increased download on the stabilizer. This is caused by increased slipstream. As the pitch attitude increases and the airspeed decreases, progressively more right rudder must be applied to compensate for propeller effects and to hold a constant heading.

After the climb is established, back-elevator pressure must be maintained to keep the pitch attitude constant. As the airspeed decreases, the elevators will try to return to their neutral or streamlined position, and the airplane’s nose will tend to lower. Noseup elevator trim should be used to compensate for this so that the pitch attitude can be maintained without holding back-elevator pressure. Throughout the climb, since the power is fixed at the climb power setting, the airspeed is controlled by the use of elevator.

A cross-check of the airspeed indicator, attitude indicator, and the position of the airplane’s nose in relation to the horizon will determine if the pitch attitude is correct. At the same time, a constant heading should be held with the wings level if a straight climb is being performed, or a constant angle of bank and rate of turn if a climbing turn is being performed.

To return to straight-and-level flight from a climb, it is necessary to initiate the level-off at approximately 10 percent of the rate of climb. For example, if the airplane is climbing at 500 feet per minute (FPM), leveling off should start 50 feet below the desired altitude. The nose must be lowered gradually because a loss of altitude will result if the pitch attitude is changed to the level flight position without allowing the airspeed to increase proportionately. [Figure 4-12]

After the airplane is established in level flight at a constant altitude, climb power should be retained temporarily so that the airplane will accelerate to the cruise airspeed more rapidly. When the speed reaches the desired cruise speed, the throttle setting and the propeller control (if equipped) should be set to the cruise power setting and the aircraft trimmed. After allowing time for engine temperatures to stabilize, adjust the mixture control as required. In the performance of climbing turns, the following factors should be considered:

- With a constant power setting, the same pitch attitude and airspeed cannot be maintained in a bank as in a straight climb due to the increase in the total lift required.
- The degree of bank should not be too steep. A steep bank significantly decreases the rate of
climb. The bank should always remain constant.

- It is necessary to maintain a constant airspeed and constant rate of turn in both right and left turns. The coordination of all flight controls is a primary factor.
- At a constant power setting, the airplane will climb at a slightly shallower climb angle because some of the lift is being used to turn the airplane.
- Attention should be diverted from fixation on the airplane’s nose and divided equally among inside and outside references.

Figure 4-12.—Leveling off from a climb.

There are two ways to establish a climbing turn. Either establish a straight climb and then turn, or enter the climb and turn simultaneously. Climbing turns should be used when climbing to the local practice area. Climbing turns allow better visual scanning, and it is easier for other pilots to see a turning aircraft.

In any turn, the loss of vertical lift and increased induced drag, due to increased angle of attack, becomes greater as the angle of bank is increased. So shallow turns should be used to maintain an efficient rate of climb.

DESCENTS

A descent, or glide, is a basic maneuver in which the airplane loses altitude in a controlled descent with little or no engine power. Forward motion is maintained by the component of weight acting along the flightpath, and the pilot balancing the forces of gravity and lift controls the descent rate. [Figure 4-13]

Although power-off descents are related to the practice of power-off accuracy landings, as will be covered in chapter 7, they have a specific purpose in simulated emergency landings. Descents must be performed with a high degree of proficiency because during approaches to landings, the pilot will be dividing his or her attention to details inside and outside the cockpit.
The glide ratio of an airplane is the distance the airplane will glide power-off from a given altitude. For instance, if an airplane travels 10,000 feet forward while descending 1,000 feet, its glide ratio is 10 to 1.

The glide ratio is affected by all four forces that act on an airplane (weight, lift, drag, and thrust). If all factors are in balance, the glide ratio will be constant. Although the effect of wind will not be covered in this section, it is an obvious factor that affects the gliding distance in relation to its movement over the ground. With a tailwind, the airplane will glide farther because of the higher groundspeed. With a headwind, the airplane will not glide as far because of the slower groundspeed.

Variations in weight do not affect the glide angle provided the pilot uses the correct airspeed. Since it is the lift over drag (L/D) ratio that determines the distance an airplane can glide, weight will not affect the distance. The glide ratio is based only on the relationship of the aerodynamic forces acting on the airplane. The only effect the weight will have is to vary the time that the airplane will glide. For example, if two airplanes having the same L/D ratio, but different weights, start a glide from the same altitude, the heavier airplane gliding at a higher airspeed will arrive at the touchdown point in a shorter time. Both airplanes will cover the same distance, only the lighter airplane will take a longer time. [Figure 4-14]

Under various flight conditions, the drag factor may be changed through the operation of the landing gear and/or flaps. When the landing gear or the flaps are lowered, the drag is increased, and the airspeed will decrease unless the nose is lowered. As the nose is lowered, the glide angle increases
and reduces the distance traveled. A power-off windmilling propeller also creates considerable drag and decreases the airplane’s forward movement. In an emergency, the propeller may be changed to full high pitch (low RPM), which reduces the frontal area of the propeller blades, and reduces drag allowing the airplane to glide farther. The use of high pitch places an additional load on the engine at idle speeds and could cause the engine to stop. In addition, when the propeller blades are at high pitch, they are not ready to deliver maximum power if needed.

Although the propeller thrust of the airplane is normally dependent on the power output of the engine, the throttle is in the closed position during a glide, so the thrust is constant. In a power-off glide, the pitch attitude must be adjusted as necessary to maintain a constant airspeed.

The best speed to use for a glide is one that will result in the greatest glide distance for a given amount of altitude. The manufacturer determines this from the L/D max curve and usually provides this information in the Pilot’s Operating Handbook (POH). Any change in the gliding airspeed will result in a proportionate change in the glide ratio. As the airspeed is reduced or increased from the optimum glide speed, the glide ratio is also changed. When below the optimum speed, the angle of descent will be greater and the airplane will not glide as far. For this reason, the pilot should never try to stretch a glide by reducing the airspeed below the airplane’s recommended best glide speed. [Figure 4-15]

![Figure 4-15. Lift/drag ratio.](image)

Pilots should perform descents by reference to both flight instruments and outside visual references. [Figure 4-16]

To enter the glide, the pilot should close the throttle and advance the propeller control (if equipped) to low pitch (high RPM). A constant altitude should be held until the airspeed decreases to the recommended best glide speed, then the nose should be lowered to maintain that gliding speed. When the speed has stabilized, the airplane should be retrimmed.

When the approximate gliding pitch attitude is established, the airspeed indicator should be checked. If the airspeed is higher than the recommended speed, the nose is too low. If the airspeed is less than the recommended speed, the nose is too high, and the pitch attitude should be readjusted accordingly. When the proper glide has been established, flaps may be used. The nose attitude will have to be lowered accordingly to maintain the desired glide speed. Again, the pitch attitude should
be adjusted first, and then the airspeed checked to be sure that a constant airspeed is being maintained. It is always best to establish the proper flight attitude by establishing the visual reference first, then use the flight instruments as a secondary check.

Figure 4-16.—Outside and flight instrument references for a glide.

In order to maintain the most efficient glide in a turn, more altitude will be sacrificed than in a straight glide since this is the only way speed can be maintained without power. Turning in a glide decreases the glide performance of the airplane to an even greater extent than a normal turn with power.

The level-off from a glide must be started before reaching the desired altitude. This is necessary because of the airplane’s downward inertia. The amount of lead depends upon the rate of descent and the pilot’s control technique. With too little lead, there will be a tendency to descend below the selected altitude. For example, assuming a 500-FPM rate of descent, the altitude must be led by approximately 100 to 200 feet to level off at a higher airspeed than the glide speed. The higher the rate of descent, the greater the lead. At the selected lead point, the power should be advanced smoothly to the level flight cruise power setting. Since the nose will tend to rise due to increased slipstream over the stabilizer and the airspeed increases, the pilot should smoothly change the pitch attitude so that level flight is attained at the desired altitude. [Figure 4-17]
Figure 4-17.—Leveling off from a descent.
CHAPTER 5 - SLOW FLIGHT, STALLS, AND SPINS

INTRODUCTION

This chapter provides the recommended procedures for the safe operation of an airplane at airspeeds less than cruise. The discussion includes slow flight; flight at minimum controllable airspeed; and information on stall and spin recognition, characteristics, and recovery.

SLOW FLIGHT

Slow flight can be defined as flight at any airspeed that is less than cruise airspeed. Flight instructors should have their students maneuver the airplane at airspeeds and in configurations that will be encountered during takeoffs, climbs, descents, go-around and approaches to landing. Flight should also be practiced at the slowest airspeed at which the airplane is capable of maintaining controlled flight without stalling, usually at 3 to 5 knots above stalling speed.

Maneuvering during slow flight

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 of any airplane is of great importance to pilots. Pilot's must develop this awareness in order to avoid stalls in any airplane flown at the slower airspeeds which are characteristic during takeoffs, climbs, descents, go-arounds, and approaches to landing. Maintaining sufficient lift and adequate control of an airplane during performance maneuvers depends upon a certain minimum airspeed.

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. It is important that pilots form the habit of frequently referencing flight instruments for airspeed, altitude, and attitude indications while flying at slow speeds.

To begin the maneuver the throttle is gradually reduced from cruising position. While the airplane is losing airspeed, the position of the nose in relation to the horizon should be noted and should be raised as necessary to maintain altitude. [Figure 5-1] When the airspeed is below the maximum allowable for landing gear operation, the landing gear (if equipped with retractable gear) is extended and all gear-down checks performed. As the airspeed drops below the maximum allowable speed for flap operation, flaps are lowered and the pitch attitude adjusted to maintain altitude. Power and pitch attitude is now adjusted to maintain the altitude and airspeed desired.

During these changing flight conditions it is important to retrim the airplane as often as necessary to compensate for changes in control pressures. 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 airspeed have been established, it is important to continually cross-check the, altimeter, and airspeed indicator, as well as outside references, to ensure that accurate control is being maintained.

Figure 5-1.— Flight at minimum controllable airspeed.
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 selected airspeed. During the turns, power and pitch attitude may need to be increased to maintain the airspeed and altitude. If a steep turn is made, the increase in angle of attack to maintain altitude may result in a stall. A stall may also occur as a result of abrupt or rough control movements when flying at slow flight. Abruptly raising the flaps during slow flight will also result in lift suddenly being lost, causing the airplane to lose altitude or perhaps stall.

Once flight at a selected airspeed is set up properly for level flight, a descent or climb at the selected airspeed, can be established by adjusting the power to maintain the desired airspeed, and simultaneously adjusting the pitch attitude as necessary to establish the desired rate of descent or climb.

**Maneuvering during slow flight at minimum airspeed**

Slow flight should also be practiced at just above stall speed. By definition, the term “flight at minimum 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. This airspeed will depend upon various circumstances, such as the gross weight and CG location of the airplane and maneuvering load imposed by turns and pullups. Flight at minimum airspeed should include climbs, turns, and descents. Flight at minimum airspeed requires positive use of rudder and ailerons to counteract asymmetrical loading of the propeller, the action of the corkscrewing slipstream, and torque reaction. Rolling in and out of turns requires more rudder then rolling at normal airspeeds because of the greater displacement of the ailerons at minimum airspeed. A positive climb, however, may not be possible at altitude due to a lack of available power in excess of that required to maintain straight-and-level flight at the minimum airspeed. In some airplanes, an attempt to climb at such a slow airspeed may result in a loss of altitude, even with maximum power applied.

Flight at minimum airspeed will help pilots develop the ability to estimate the margin of safety above the stalling speed by the diminishing effectiveness of the flight controls.

**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 5-2]

![Figure 5-2.— Airflow around a wing at various angles of attack.](image)

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 (RPM) 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.

The feeling of control pressures is also 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. The 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.

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 5-3] Though the recovery actions must be taken in a coordinated manner, they are broken down into three steps 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 speed and assist in reducing the wing’s angle of attack. Generally, the throttle should be promptly, but smoothly, advanced to the maximum allowable power.

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 RPM) 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. Recovery should be practiced first without the addition of power, and then with the addition of power to determine how effective power will be in executing a safe recovery. 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 an application of power, reduction in the angle of attack (lowering the airplane's pitch attitude), and termination of the descent without entering another 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. Such a design feature causes the wingtips to have a smaller angle of attack than the wing roots during flight. [Figure 5-4]

![Figure 5-4.—Wingtip washout.](image)

Exceeding the critical angle of attack causes a stall, and the wing roots of an airplane will exceed the critical angle before the wingtips, and the wing roots will stall first. The wings are designed in this manner so that aileron control will be available at high angles of attack (slow airspeed) and give the airplane more stable stalling characteristics.

When the airplane is in a stalled condition, the wingtips continue to provide some degree of lift, and the ailerons still have some control effect. During recovery from a stall, the return of lift begins at the tips and progresses toward the roots. Thus, the ailerons can be used to level the wings.

Using the ailerons requires finesse to avoid an aggravated stall condition. For example, if the right wing dropped during the stall and excessive aileron control were applied to the left to raise the wing, the aileron deflected downward (right wing) would produce a greater angle of attack (and drag), and possibly a more complete stall at the tip as the critical angle of attack is exceeded. The increase in drag created by the high angle of attack on that wing might cause the airplane to yaw in that direction. This adverse yaw could result in a spin unless directional control was maintained by rudder, and/or the aileron control sufficiently reduced. Even though excessive aileron pressure may have been applied, a spin will not occur if directional (yaw) control is maintained by timely application of
coordinated rudder pressure. Therefore, it is important that the rudder be used properly during both the entry and the recovery from a stall. The primary use of the rudder in stall recoveries is to counteract any tendency of the airplane to yaw or slip. The correct recovery technique would be to decrease the pitch attitude by applying forward-elevator pressure to break the stall, advancing the throttle to increase airspeed, and simultaneously maintaining directional control with coordinated use of the aileron and rudder.

**Stall Characteristics**

Because of engineering design variations, the stall characteristics for all airplanes cannot be specifically described; however, the similarities found in small general aviation training-type airplanes are noteworthy enough to be considered. It will be noted that the power-on and power-off stall warning indications will be different. The power-off stall will have less noticeable clues (buffeting, shaking) than the power-on stall. In the power-off stall, the predominant clue can be the elevator control position (full-up elevator against the stops) and a high descent rate. When performing the power-on stall, the buffeting will likely be the predominant clue that provides a positive indication of the stall. For the purpose of airplane certification, the stall warning may be furnished either through the inherent aerodynamic qualities of the airplane, or by a stall warning device that will give a clear distinguishable indication of the stall. Most airplanes are equipped with a stall warning device.

The factors that affect the stalling characteristics of the airplane are balance, bank, pitch attitude, coordination, drag, and power. The pilot should learn the effect of the stall characteristics of the airplane being flown and the proper correction. It should be reemphasized that a stall can occur at any airspeed, in any attitude, or at any power setting, depending on the total number of factors affecting the particular airplane.

A number of factors may be induced as the result of other factors. For example, when the airplane is in a nose-high turning attitude, the angle of bank has a tendency to increase. This occurs because with the airspeed decreasing, the airplane begins flying in a smaller and smaller arc. Since the outer wing is moving in a larger radius and traveling faster than the inner wing, it has more lift and causes an overbanking tendency. At the same time, because of the decreasing airspeed and lift on both wings, the pitch attitude tends to lower. In addition, since the airspeed is decreasing while the power setting remains constant, the effect of torque becomes more prominent, causing the airplane to yaw.

During the practice of power-on turning stalls, to compensate for these factors and to maintain a constant flight attitude until the stall occurs, aileron pressure must be continually adjusted to keep the bank attitude constant. At the same time, back-elevator pressure must be continually increased to maintain the pitch attitude, as well as right-rudder pressure increased to keep the ball centered and to prevent adverse yaw from changing the turn rate. If the bank is allowed to become too steep, the vertical component of lift decreases and makes it even more difficult to maintain a constant-pitch attitude.

Whenever practicing turning stalls, a constant pitch-and-bank attitude should be maintained until the stall occurs. Whatever control pressures are necessary should be applied even though the controls appear to be crossed (aileron pressure in one direction, rudder pressure in the opposite direction). During the entry to a power-on turning stall to the right, in particular, the controls will be crossed to some extent. This is due to right-rudder pressure being used to overcome torque and left aileron pressure being used to prevent the bank from increasing.
Approaching Stalls—Power-On or Power-Off

An approaching stall is one in which the airplane is approaching a stall but is not allowed to completely stall. This stall maneuver is primarily for practice in retaining (or regaining) full control of the airplane immediately upon recognizing that it is almost in a stall or that a stall is likely to occur if timely preventive action is not taken.

The practice of these stalls is of particular value in developing the pilot’s sense of feel for executing maneuvers in which maximum airplane performance is required. These maneuvers require flight with the airplane approaching a stall, and recovery initiated before a stall occurs. As in all maneuvers that involve significant changes in altitude or direction, the pilot must ensure that the area is clear of other air traffic before executing the maneuver.

These stalls may be entered and performed in the attitudes and with the same configuration of the basic full stalls or other maneuvers described in this chapter. However, instead of allowing a complete stall, when the first buffeting or decay of control effectiveness is noted, the angle of attack must be reduced immediately by releasing the back-elevator pressure and applying whatever additional power is necessary. Since the airplane will not be completely stalled, the pitch attitude needs to be decreased only to a point where minimum controllable airspeed is attained or until adequate control effectiveness is regained.

The pilot must promptly recognize the indication of a stall and take timely, positive control action to prevent a stall.

Power-Off Stalls

The practice of power-off stalls is usually performed with normal landing approach conditions in simulation of an accidental stall occurring during landing approaches. Airplanes equipped with flaps and/or retractable landing gear should be in the landing configuration. Airspeed in excess of the normal approach speed should not be carried into a stall entry since it could result in an abnormally nose-high attitude. Before executing these practice stalls, the pilot must be sure the area is clear of other air traffic.

After extending the landing gear, applying carburetor heat (if applicable), and retarding the throttle to idle (or normal approach power), the airplane should be held at a constant altitude in level flight until the airspeed decelerates to that of a normal approach. The airplane should then be smoothly nosed down into the normal approach attitude to maintain that airspeed. Wing flaps should then be extended and pitch attitude adjusted to maintain the airspeed. When the approach attitude and airspeed have stabilized, the airplane’s nose should be smoothly raised to an attitude that will induce a stall. [Figure 5-5] Directional control should be maintained with the rudder, the wings held level by
use of the ailerons, and a constant-pitch attitude maintained with the elevator until the stall occurs. The stall will be recognized by clues, such as full-up elevator, high descent rate, uncontrollable nosedown pitching, and possible buffeting.

Recovering from the stall should be accomplished by reducing the angle of attack, releasing back-elevator pressure, and advancing the throttle to maximum allowable power. Right-rudder pressure is necessary to overcome the engine torque effects as power is advanced and the nose is being lowered.

The nose should be lowered as necessary to regain flying speed and returned to straight-and-level flight attitude. After establishing a positive rate of climb, the flaps and landing gear are retracted, as necessary, and when in level flight, the throttle should be returned to cruise power setting. After recovery is complete, a climb or go-around procedure should be initiated, as the situation dictates, to assure a minimum loss of altitude.

Recovery from power-off stalls should also be practiced from shallow banked turns to simulate an inadvertent stall during a turn from base leg to final approach. During the practice of these stalls, care should be taken that the turn continues at a uniform rate until the complete stall occurs. If the power-off turn is not properly coordinated while approaching the stall, wallowing may result when the stall occurs. If the airplane is in a slip, the outer wing may stall first and whip downward abruptly. This does not affect the recovery procedure in any way; the angle of attack must be reduced, the heading maintained, and the wings leveled by coordinated use of the controls. In the practice of turning stalls, no attempt should be made to stall the airplane on a predetermined heading. However, to simulate a turn from base to final approach, the stall normally should be made to occur within a heading change of approximately 90°.

After the stall occurs, the recovery should be made straight ahead with minimum loss of altitude, and accomplished in accordance with the recovery procedure discussed earlier. Recoveries from power-off stalls should be accomplished both with, and without, the addition of power, and may be affected either just after the stall occurs, or after the nose has pitched down through the level flight attitude.

**Power-On Stalls**

Power-on stall recoveries are practiced from straight climbs, and climbing turns with 15 to 20° banks, to simulate an accidental stall occurring during takeoffs and climbs. Airplanes equipped with flaps and/or retractable landing gear should normally be in the takeoff configuration; however, power-on stalls should also be practiced with the airplane in a clean configuration (flaps and/or gear retracted) as in departure and normal climbs. [Figure 5-6] After establishing the takeoff or climb configuration, the airplane should be slowed to the normal lift-off speed while clearing the area for other air traffic. When the desired speed is attained, the power should be set at takeoff power for the takeoff stall or the recommended climb power for the departure stall while establishing a climb attitude. The purpose
of reducing the airspeed to lift-off airspeed before the throttle is advanced to the recommended setting is to avoid an excessively steep noseup attitude for a long period before the airplane stalls.

After the climb attitude is established, the nose is then brought smoothly upward to an attitude obviously impossible for the airplane to maintain and is held at that attitude until the full stall occurs. In most airplanes, after attaining the stalling attitude, the elevator control must be moved progressively further back as the airspeed decreases until, at the full stall, it will have reached its limit and cannot be moved back any farther.

Recovery from the stall should be accomplished by immediately reducing the angle of attack by positively releasing back-elevator pressure and smoothly advancing the throttle to maximum allowable power. In this case, since the throttle is already at the climb power setting, the addition of power will be relatively slight.

The nose should be lowered as necessary to regain flying speed with the minimum loss of altitude. Then, the airplane should be returned to the normal straight-and-level flight attitude, and when in normal level flight, the throttle should be returned to cruise power setting.

The pilot must recognize instantly when the stall has occurred and take prompt action to prevent a prolonged stalled condition.

Figure 5-7.—Secondary stall.

Secondary Stall

This stall is called a secondary stall since it may occur after a recovery from a preceding stall. It is caused by attempting to hasten the completion of a stall recovery before the airplane has regained sufficient flying speed. When this stall occurs, the back-elevator pressure should again be released just as in a normal stall recovery. When sufficient airspeed has been regained, the airplane can then be returned to straight-and-level flight. [Figure 5-7]

This stall usually occurs when the pilot uses abrupt control input to return to straight-and-level flight after a stall or spin recovery.

Accelerated Stalls

Though the stalls just discussed normally occur at a specific airspeed, the pilot must thoroughly understand that all stalls result solely from attempts to fly at excessively high angles of attack. During
flight, the angle of attack of an airplane wing is determined by a number of factors, the most important of which are the airspeed, the gross weight of the airplane, and the load factors imposed by maneuvering.

At the same gross weight, airplane configuration, and power setting, a given airplane will consistently stall at the same indicated airspeed if no acceleration is involved. The airplane will, however, stall at a higher indicated airspeed when excessive maneuvering loads are imposed by steep turns, pullups, or other abrupt changes in its flightpath. Stalls entered from such flight situations are called “accelerated maneuver stalls,” a term, which has no reference to the airspeeds involved. [Figure 5-8]

Stalls which result from abrupt maneuvers tend to be more rapid, or severe, than the unaccelerated stalls, and because they occur at higher-than-normal airspeeds, they may be unexpected by an inexperienced pilot. Failure to take immediate steps toward recovery when an accelerated stall occurs may result in a complete loss of flight control, notably, power-on spins.

This stall should never be practiced with wing flaps in the extended position due to the lower “G” load limitations in that configuration.

Accelerated maneuver stalls should not be performed in any airplane, which is prohibited from such maneuvers by its type certification restrictions or Airplane Flight Manual (AFM) and/or Pilot’s Operating Handbook (POH). If they are permitted, they should be performed with a bank of approximately 45°, and in no case at a speed greater than the airplane manufacturer’s recommended airspeeds or the design maneuvering speed specified for the airplane. The design maneuvering speed is the maximum speed at which the airplane can be stalled or full available aerodynamic control will not exceed the airplane’s limit load factor. At or below this speed, the airplane will usually stall before the limit load factor can be exceeded. Those speeds must not be exceeded because of the extremely high structural loads that are imposed on the airplane, especially if there is turbulence. In most cases, these stalls should be performed at no more than 1.2 times the normal stall speed.

Figure 5-8.—Accelerated stall.

The objective of demonstrating accelerated stalls is not to develop competency in setting up the stall, but rather to learn how they may occur and to develop the ability to recognize such stalls immediately, and to take prompt, effective recovery action. It is important that recoveries are made at the first indication of a stall, or immediately after the stall has fully developed; a prolonged stall condition should never be allowed.
An airplane will stall during a coordinated steep turn exactly as it does from straight flight, except that the pitching and rolling actions tend to be more sudden. If the airplane is slipping toward the inside of the turn at the time the stall occurs, it tends to roll rapidly toward the outside of the turn as the nose pitches down because the outside wing stalls before the inside wing. If the airplane is skidding toward the outside of the turn, it will have a tendency to roll to the inside of the turn because the inside wing stalls first. If the coordination of the turn at the time of the stall is accurate, the airplane’s nose will pitch away from the pilot just as it does in a straight flight stall, since both wings stall simultaneously.

An accelerated stall demonstration is entered by establishing the desired flight attitude, then smoothly, firmly, and progressively increasing the angle of attack until a stall occurs. Because of the rapidly changing flight attitude, sudden stall entry, and possible loss of altitude, it is extremely vital that the area be clear of other aircraft and the entry altitude be adequate for safe recovery.

This demonstration stall, as in all stalls, is accomplished by exerting excessive back-elevator pressure. Most frequently it would occur during improperly executed steep turns, stall and spin recoveries, and pullouts from steep dives. The objectives are to determine the stall characteristics of the airplane and develop the ability to instinctively recover at the onset of a stall at other-than-normal stall speed or flight attitudes. An accelerated stall, although usually demonstrated in steep turns, may actually be encountered any time excessive back-elevator pressure is applied and/or the angle of attack is increased too rapidly.

From straight-and-level flight at maneuvering speed or less, the airplane should be rolled into a steep level flight turn and back-elevator pressure gradually applied. After the turn and bank are established, back-elevator pressure should be smoothly and steadily increased. The resulting apparent centrifugal force will push the pilot's body down in the seat, increase the wing loading, and decrease the airspeed. After the airspeed reaches the design maneuvering speed or within 20 knots above the unaccelerated stall speed, back-elevator pressure should be firmly increased until a definite stall occurs. These speed restrictions must be observed to prevent exceeding the load limit of the airplane.

When the airplane stalls, recovery should be made promptly, by releasing sufficient back-elevator pressure and increasing power to reduce the angle of attack. If an uncoordinated turn is made, one wing may tend to drop suddenly, causing the airplane to roll in that direction. If this occurs, power must be added, the excessive back-elevator pressure released, and the airplane returned to straight-and-level flight with coordinated control pressure.

The pilot should recognize when the stall is imminent and take prompt action to prevent a completely stalled condition. It is imperative that a prolonged stall, excessive airspeed, excessive loss of altitude, or spin be avoided.

**Cross-Control Stall**

The objective of a cross-control stall demonstration maneuver is to show the effect of improper control technique and to emphasize the importance of using coordinated control pressures whenever making turns. This type of stall occurs with the controls crossed—aileron pressure applied in one direction and rudder pressure in the opposite direction.

In addition, when excessive back-elevator pressure is applied, a cross-control stall may result.

This is a stall that is most apt to occur during a poorly planned and executed base-to-final approach turn, and often is the result of overshooting the centerline of the runway during that turn. Normally,
the proper action to correct for overshooting the runway is to increase the rate of turn by using coordinated aileron and rudder. At the relatively low altitude of a base-to-final approach turn, improperly trained pilots may be apprehensive of steepening the bank to increase the rate of turn, and rather than steepening the bank, they hold the bank constant and attempt to increase the rate of turn by adding more rudder pressure in an effort to align it with the runway.

The addition of inside rudder pressure will cause the speed of the outer wing to increase therefore, creating greater lift on that wing. To keep that wing from rising and to maintain a constant angle of bank, opposite aileron pressure needs to be applied. The added inside rudder pressure will also cause the nose to lower in relation to the horizon. Consequently, additional back-elevator pressure would be required to maintain a constant-pitch attitude. The resulting condition is a turn with rudder applied in one direction, aileron in the opposite direction, and excessive back-elevator pressure—a pronounced cross-control condition.

Since the airplane is in a skidding turn during the cross-control condition, the wing on the outside of the turn speeds up and produces more lift than the inside wing; thus, the airplane starts to increase its bank. The down aileron on the inside of the turn helps drag that wing back, slowing it up and decreasing its lift, which requires more aileron application. This further causes the airplane to roll. The roll may be so fast that it is possible the bank will be vertical or past vertical before it can be stopped.

For the demonstration of the maneuver, it is important that it be entered at a safe altitude because of the possible extreme nosedown attitude and loss of altitude that may result. Before demonstrating this stall, the pilot should clear the area for other air traffic while slowly retarding the throttle. Then the landing gear (if retractable gear) should be lowered, the throttle closed, and the altitude maintained until the airspeed approaches the normal glide speed. Because of the possibility of exceeding the airplane’s limitations, flaps should not be extended. While the gliding attitude and airspeed are being established, the airplane should be retrimmed. When the glide is stabilized, the airplane should be rolled into a medium-banked turn to simulate a final approach turn that would overshoot the centerline of the runway. During the turn, excessive rudder pressure should be applied in the direction of the turn but the bank held constant by applying opposite aileron pressure. At the same time, increased back-elevator pressure is required to keep the nose from lowering.

All of these control pressures should be increased until the airplane stalls. When the stall occurs, recovery is made by releasing the control pressures and increasing power as necessary to recover.

In a cross-control stall, the airplane often stalls with little warning. The nose may pitch down, the inside wing may suddenly drop, and the airplane may continue to roll to an inverted position. This is usually the beginning of a spin. It is obvious that close to the ground is no place to allow this to happen.

Recovery must be made before the airplane enters an abnormal attitude (vertical spiral or spin); it is a simple matter to return to straight-and-level flight by coordinated use of the controls. The pilot must be able to recognize when this stall is imminent and must take immediate action to prevent a completely stalled condition. It is imperative that this type of stall not occur during an actual approach to a landing, since recovery may be impossible prior to ground contact due to the low altitude.
Elevator Trim Stall

The elevator trim stall maneuver shows what can happen when full power is applied for a go-around and positive control of the airplane is not maintained. Such a situation may occur during a go-around procedure from a normal landing approach or a simulated forced-landing approach, or immediately after a takeoff. The objective of the demonstration is to show the importance of making smooth power applications, overcoming strong trim forces and maintaining positive control of the airplane to hold safe flight attitudes, and using proper and timely trim techniques. [Figure 5-9]

At a safe altitude and after ensuring that the area is clear of other air traffic, the pilot should slowly retard the throttle and extend the landing gear (if retractable gear). One-half to full flaps should be lowered, the throttle closed, and altitude maintained until the airspeed approaches the normal glide speed. When the normal glide is established, the airplane should be trimmed for the glide just as would be done during a landing approach (noseup trim). During this simulated final approach glide, the throttle is then advanced smoothly to maximum allowable power as would be done in a go-around procedure. The combined forces of thrust, torque, and back-elevator trim will tend to make the nose rise sharply and turn to the left.

When the throttle is fully advanced and the pitch attitude increases above the normal climbing attitude and it is apparent that a stall is approaching, adequate forward pressure must be applied to return the airplane to the normal climbing attitude. While holding the airplane in this attitude, the trim should then be adjusted to relieve the heavy control pressures and the normal go-around and level-off procedures completed.

The pilot should recognize when a stall is approaching, and takes prompt action to prevent a completely stalled condition. It is imperative that a stall not occur during an actual go-around from a landing approach.

SPINS

A spin may be defined as an aggravated stall that results in what is termed “autorotation” wherein the airplane follows a downward corkscrew path. As the airplane rotates around a vertical axis, the rising wing is less stalled than the descending wing creating a rolling, yawing, and pitching motion. The airplane is basically being forced downward by gravity, rolling, yawing, and pitching in a spiral path. [Figure 5-10]

The autorotation results from an unequal angle of attack on the airplane’s wings. The rising wing has a decreasing angle of attack, where the relative lift increases and the drag decreases. In effect, this
wing is less stalled. Meanwhile, the descending wing has an increasing angle of attack, past the
wing’s critical angle of attack (stall) where the relative lift decreases and drag increases.

A spin is caused when the airplane’s wing exceeds its critical angle of attack (stall) with a side slip or
yaw acting on the airplane at, or beyond, the actual stall. During this uncoordinated maneuver, a pilot
may not be aware that a critical angle of attack has been exceeded until the airplane yaws out of
control toward the lowering wing. If stall recovery is not initiated immediately, the airplane may enter
a spin.

If this stall occurs while the airplane is in a slipping or skidding turn, this can result in a spin entry
and rotation in the direction that the rudder is being applied, regardless of which wingtip is raised.

Many airplanes have to be forced to spin and require considerable judgment and technique to get the
spin started. These same airplanes that have to be forced to spin, may be accidentally put into a spin
by mishandling the controls in turns, stalls, and flight at minimum controllable airspeeds. This fact is
additional evidence of the necessity for the practice of stalls until the ability to recognize and recover
from them is developed.

Often a wing will drop at the beginning of a stall. When this happens, the nose will attempt to move
(yaw) in the direction of the low wing. This is where use of the rudder is important during a stall. The
correct amount of opposite rudder must be applied to keep the nose from yawing toward the low
wing. By maintaining directional control and not allowing the nose
to yaw toward the low wing, before stall recovery is initiated, a spin
will be averted. If the nose is allowed to yaw during the stall, the
airplane will begin to slip in the direction of the lowered wing, and
will enter a spin. An airplane must be stalled in order to enter a spin;
therefore, continued practice in stalls will help the pilot develop a
more instinctive and prompt reaction in recognizing an approaching
spin. It is essential to learn to apply immediate corrective action any
time it is apparent that the airplane is nearing spin conditions. If it
is impossible to avoid a spin, the pilot should immediately execute
spin recovery procedures.

Figure 5-10.—Two-turn spin.

SPIN PROCEDURES

The flight instructor should demonstrate spins. Special spin
procedures or techniques required for a particular airplane are not
presented here. Before beginning any spin operations, the following
items should be reviewed:

- The airplane’s AFM/POH limitations section, placards, or type
certification data, to determine if the airplane is approved for
spins.
- Weight and balance limitations.
- Recommended entry and recovery procedures.
- The requirements for parachutes.

A thorough airplane preflight should be accomplished with special
emphasis on excess or loose items that may affect the weight, CG,
and controllability of the airplane. Slack or loose control cables (particularly rudder and elevator) could prevent full anti-spin control deflections and delay or preclude recovery in some airplanes.

Prior to beginning spin training, the flight area, above and below the airplane, must be clear of other air traffic. This may be accomplished while slowing the airplane for the spin entry. All spin training should be initiated at an altitude high enough for a completed recovery at or above 1,500 feet AGL.

It may be appropriate to introduce spin training by first practicing both power-on and power-off stalls, in a clean configuration. This practice would be used to familiarize the student with the airplane’s specific stall and recovery characteristics. Care should be taken with the handling of the power (throttle) in entries and during spins. Carburetor heat should be applied according to the manufacturer’s recommendations.

There are four phases of a spin: entry, incipient, developed, and recovery.

**Entry Phase**

The entry phase is where the pilot provides the necessary elements for the spin, either accidentally or intentionally. The entry procedure for demonstrating a spin is similar to a power-off stall. During the entry, the power should be reduced slowly to idle, while simultaneously raising the nose to a pitch attitude that will ensure a stall. As the airplane approaches a stall, smoothly apply full rudder in the direction of the desired spin rotation while applying full back (up) elevator to the limit of travel. Always maintain the ailerons in the neutral position during the spin procedure unless AFM/POH specifies otherwise.

**Incipient Phase**

The incipient phase is from the time the airplane stalls and rotation starts until the spin has fully developed. This change may take up to two turns for most aircraft. Incipient spins that are not allowed to develop into a steady-state spin are the most commonly used in the introduction to spin training and recovery techniques. In this phase, the aerodynamic and inertial forces have not achieved a balance. As the incipient spin develops, the indicated airspeed should be near or below stall airspeed, and the turn-and-slip indicator should indicate the direction of the spin.

The incipient spin recovery procedure should be commenced prior to the completion of 360° of rotation. The pilot should apply full rudder opposite the direction of rotation. If the pilot is not sure of the direction of the spin, check the turn-and-slip indicator; it will show a deflection in the direction of rotation.

**Developed Phase**

The developed phase occurs when the airplane’s angular rotation rate, airspeed, and vertical speed are stabilized while in a flight path that is nearly vertical. This is where airplane aerodynamic forces and inertial forces are in balance, and the attitude, angles, and self-sustaining motions about the vertical axis are constant or repetitive. The spin is in equilibrium.

**Recovery Phase**

The recovery phase occurs when the angle of attack of the wings decreases below the critical angle of attack and autorotation slows. Then the nose becomes steeper and rotation stops. This phase may last for a quarter turn to several turns.

To recover, control inputs are initiated to disrupt the spin equilibrium by stopping the rotation and stall. To accomplish spin recovery, the manufacturer’s recommended procedures should be followed.
In the absence of the manufacturer’s recommended spin recovery procedures and techniques, the following spin recovery procedures are recommended.

Step 1—REDUCE THE POWER (THROTTLE) TO IDLE. Power aggravates the spin characteristics. It usually results in a flatter spin attitude and increased rotation rates.

Step 2—POSITION THE AILERONS TO NEUTRAL. Ailerons may have an adverse effect on spin recovery. Aileron control in the direction of the spin may speed up the rate of rotation and delay the recovery. Aileron control opposite the direction of the spin may cause the down aileron to move the wing deeper into the stall and aggravate the situation. The best procedure is to ensure that the ailerons are neutral.

Step 3—APPLY FULL OPPOSITE RUDDER AGAINST THE ROTATION. Make sure that full (against the stop) opposite rudder has been applied.

Step 4—APPLY A POSITIVE AND BRISK, STRAIGHT FORWARD MOVEMENT OF THE ELEVATOR CONTROL FORWARD OF THE NEUTRAL TO BREAK THE STALL. This should be done immediately after full rudder application. The forceful movement of the elevator will decrease the excessive angle of attack and break the stall. The controls should be held firmly in this position. When the stall is “broken,” the spinning will stop.

Step 5—AFTER SPIN ROTATION STOPS, NEUTRALIZE THE RUDDER. If the rudder is not neutralized at this time, the ensuing increased airspeed acting upon a deflected rudder will cause a yawing or skidding effect.

Slow and overly cautious control movements during spin recovery must be avoided. In certain cases it has been found that such movements result in the airplane continuing to spin indefinitely, even with anti-spin inputs. A brisk and positive technique on the other hand, results in a more positive spin recovery.

Step 6—BEGIN APPLYING BACK-ELEVATOR PRESSURE TO RAISE THE NOSE TO LEVEL FLIGHT. Caution must be used not to apply excessive back-elevator pressure after the rotation stops. Excessive back-elevator pressure can cause a secondary stall and result in another spin. Care should be taken not to exceed the “G” load limits and airspeed limitations during recovery. If the flaps and/or retractable landing gear are extended prior to the spin, they should be retracted as soon as possible after spin entry.

It is important to remember that the above-spin recovery procedures and techniques are recommended for use only in the absence of the manufacturer’s procedures. Before any pilot attempts to begin spin training, he or she must be familiar with the procedures provided by the manufacturer for spin recovery.

The most common problems in spin recovery include, pilot confusion as to the direction of spin rotation, and whether the maneuver is a spin versus spiral. If the airspeed is increasing, the airplane is no longer in a spin but in a spiral.

**AIRCRAFT LIMITATIONS**

The official sources for determining if the spin maneuver IS APPROVED or NOT APPROVED for a specific airplane are:

- Type Certificate Data Sheets or the Aircraft Specifications.
• The limitation section of the JAA-approved AFM/POH. The limitation sections may provide additional specific requirements for spin authorization, such as limiting gross weight, CG range, and amount of fuel.

• On a placard located in clear view of the pilot in the airplane, NO ACROBATIC MANEUVERS INCLUDING SPINS APPROVED. In airplanes placarded against spins, there is no assurance that recovery from a fully developed spin is possible.

WEIGHT AND BALANCE REQUIREMENTS

With each airplane that is approved for spinning, the weight and balance requirements are important for safe performance and recovery from the spin maneuver. Pilots must be aware that just minor weight or balance changes can affect the airplane’s spin recovery characteristics. Such changes can either alter or enhance the spin maneuver and/or recovery characteristics. For example, if the addition of weight in the aft baggage compartment, or additional fuel, may still permit the airplane to be operated within CG, it could seriously affect the spin and recovery characteristics.

An airplane that may be difficult to spin intentionally in the Utility Category (restricted aft CG and reduced weight) could have less resistance to spin entry in the Normal Category (less restricted aft CG and increased weight). This situation is due to the airplane being able to generate a higher angle of attack and load factor. Furthermore, an airplane that is approved for spins in the Utility Category, but loaded in the Normal Category, may not recover from a spin that is allowed to progress beyond the incipient phase.
CHAPTER 6 - GROUND REFERENCE AND PERFORMANCE MANEUVERS

INTRODUCTION

This chapter describes the flight training maneuvers and related factors that are useful in developing pilot skills. Although most of these maneuvers are not performed in normal everyday flying, the elements and principles are applicable to performance of customary pilot operations. They aid the pilot in analyzing the effect of wind and other forces acting on the airplane and in developing a fine control touch, coordination, and division of attention for accurate and safe maneuvering of the airplane. The pilot should acquire a thorough understanding of the factors involved and the procedures recommended in this chapter.

MANEUVERING BY REFERENCE TO GROUND OBJECTS

Ground track or ground reference maneuvers are performed at a relatively low altitude while applying wind drift correction as needed to follow a predetermined track or path over the ground. They are designed to develop the ability to control the airplane, and to recognize and correct for the effect of wind while dividing attention among other matters. This requires planning ahead of the airplane, maintaining orientation in relation to ground objects, flying appropriate headings to follow a desired ground track, and being cognizant of other air traffic in the immediate vicinity.

The altitude should be low enough to easily recognize drift, but in no case lower than 500 feet above the highest obstruction. The altitude flown should be approximately 600 to 1,000 feet above the ground (the altitude usually required for airport traffic patterns). During these maneuvers, pilots should be alert for available forced-landing fields. The area chosen should be away from communities, livestock, or groups of people to prevent possible annoyance or hazards to others. Due to the altitudes at which these maneuvers are performed, there is little time available to search for a suitable field for landing in the event the need arises.

Drift and Ground Track Control

Whenever any object is free from the ground, it is affected by the medium with which it is surrounded. This means that a free object will move in whatever direction and speed that the medium moves.

For example, if a power boat crossing a river and the river were still, the boat could head directly to a point on the opposite shore and travel on a straight course to that point without drifting. However, if the river were flowing swiftly, the water current would have to be considered. That is, as the boat progresses forward with its own power, it must also move upstream at the same rate the river is moving it downstream. This is accomplished by angling the boat upstream sufficiently to counteract the downstream flow. If this is done, the boat will follow the desired track across the river from the departure point directly to the intended destination point. Should the boat not be headed sufficiently upstream, it would drift with the current and run aground at some point downstream on the opposite bank. [Figure 6-1]

As soon as an airplane becomes airborne, it is free of ground friction. Its path is then affected by the air mass in which it is flying; therefore, the airplane (like the boat) will not always track along the
ground in the exact direction that it is headed. When flying with the longitudinal axis of the airplane aligned with a road, it may be noted that the airplane gets closer to or farther from the road without any turn having been made. This would indicate that the air mass is moving sideward in relation to the airplane. Since the airplane is flying within this moving body of air (wind), it moves or drifts with the air in the same direction and speed, just like the boat moved with the river current. [Figure 6-1]

Figure 6-1.—Wind drift.

When flying straight and level and following a selected ground track, the preferred method of correcting for wind drift is to head the airplane (wind correction angle) sufficiently into the wind to cause the airplane to move forward into the wind at the same rate the wind is moving it sideways. Depending on the wind velocity, this may require a large wind correction angle or one of only a few degrees. When the drift has been neutralized, the airplane will follow the desired ground track. [Figure 6-1]

To understand the need for drift correction during flight, consider a flight with a wind velocity of 30 knots from the left and 90° to the direction the airplane is headed. After 1 hour, the body of air in which the airplane is flying will have moved 30 nautical miles (NM) to the right. Since the airplane is moving with this body of air, it too will have drifted 30 NM to the right. In relation to the air, the airplane moved forward, but in relation to the ground, it moved forward as well as 30 NM to the right.

There are times when the pilot needs to correct for drift while in a turn. [Figure 6-2] Throughout the turn the wind will be acting on the airplane from constantly changing angles. The relative wind angle and speed govern the time it takes for the airplane to progress through any part of a turn. This is due to the constantly changing groundspeed. When the airplane is headed into the wind, the groundspeed is decreased; when headed down wind, the groundspeed is increased. Through the crosswind portion of a turn, the airplane must be turned sufficiently into the wind to counteract drift. To follow a desired circular ground track, the wind correction angle must be varied in a timely manner because of the varying groundspeed as the turn progresses. The faster the groundspeed, the faster the wind correction angle must be established; the slower the groundspeed, the slower the wind correction angle may be established. It can be seen then that the steepest bank and fastest rate of turn should be made on the downwind portion of the turn and the shallowest bank and slowest rate of turn on the upwind portion.
The principles and techniques of varying the angle of bank to change the rate of turn and wind correction angle for controlling wind drift during a turn are the same for all ground track maneuvers involving changes in direction of flight.

When there is no wind, it should be simple to fly along a ground track with an arc of exactly 180° and a constant radius because the flightpath and ground track would be identical. This can be demonstrated by approaching a road at a 90° angle and, when directly over the road, rolling into a medium-banked turn, then maintaining the same angle of bank throughout the 180° of turn. [Figure 6-2]

To complete the turn, the rollout should be started at a point where the wings will become level as the airplane again reaches the road at a 90° angle and will be directly over the road just as the turn is completed. This would be possible only if there were absolutely no wind and if the angle of bank and the rate of turn remained constant throughout the entire maneuver.

If the turn were made with a constant angle of bank and a wind blowing directly across the road, it would result in a constant radius turn through the air. However, the wind effects would cause the ground track to be distorted from a constant radius turn or semicircular path. The greater the wind velocity, the greater would be the difference between the desired ground track and the flight path. To counteract this drift, the flight path can be controlled by the pilot in such a manner as to neutralize the effect of the wind, and cause the ground track to be a constant radius semicircle can control the flight path.

The effects of wind during turns can be demonstrated after selecting a road, railroad, or other ground reference that forms a straight line parallel to the wind. Fly into the wind directly over and along the line and then make a turn with a constant medium angle of bank for 360° of turn. [Figure 6-3] The airplane will return to a point directly over the line but slightly down wind from the starting point, the amount depending on the wind velocity and the time required to complete the turn. The path over the ground will be an elongated circle, although in reference to the air it is a perfect circle. Straight flight during the upwind segment after completion of the turn is necessary to bring the airplane back to the starting position.
A similar 360° turn may be started at a specific point over the reference line, with the airplane headed directly down wind. In this demonstration, the effect of wind during the constant banked turn will drift the airplane to a point where the line is reintercepted, but the 360° turn will be completed at a point down wind from the starting point.

Another reference line which lies directly crosswind may be selected and the same procedure repeated, showing that if wind drift is not corrected the airplane will, at the completion of the 360° turn, be headed in the original direction but will have drifted away from the line a distance dependent on the amount of wind.

From these demonstrations, it can be seen where and why it is necessary to increase or decrease the angle of bank and the rate of turn to achieve a desired track over the ground. The principles and techniques involved can be practiced and evaluated by the performance of the ground track maneuvers discussed in this chapter.

**Rectangular Course**

The rectangular course is a training maneuver in which the ground track of the airplane is equidistant from all sides of a selected rectangular area on the ground. While performing the maneuver, the altitude and airspeed should be held constant.

Like those of other ground track maneuvers, one of the objectives is to develop division of attention between the flightpath and ground references, while controlling the airplane and watching for other aircraft in the vicinity. Another objective is to develop recognition of drift toward or away from a line parallel to the intended ground track. This will be helpful in recognizing drift toward or from an airport runway during the various legs of the airport traffic pattern.

For this maneuver, a square or rectangular field, or an area bounded on four sides by section lines or roads (the sides of which are approximately a mile in length), should be selected well away from other air traffic. [Figure 6-4] The airplane should be flown parallel to and at a uniform distance about one-fourth to one-half mile away from the field boundaries, not above the boundaries. For best results, the flightpath should be positioned outside the field boundaries just far enough that they may be easily observed from either pilot seat by looking out the side of the airplane. If an attempt is made to fly directly above the edges of the field, the pilot will have no usable reference points to start and complete the turns. The closer the track of the airplane is to the field boundaries, the steeper the bank necessary at the turning points. Also, the pilot should be able to see the edges of the selected field while seated in a normal position and looking out the side of the airplane during either a left-hand or right-hand course. The distance of the ground track from the edges of the field should be the
same regardless of whether the course is flown to the left or right. All turns should be started when
the airplane is abeam the corner of the field boundaries, and the bank normally should not exceed
45°. These should be the determining factors in establishing the distance from the boundaries for
performing the maneuver.

Although the rectangular course may be entered from any direction, this discussion assumes entry on
a downwind.

On the downwind leg, the wind is a tailwind and results in an increased groundspeed. Consequently,
the turn onto the next leg is entered with a fairly fast rate of roll-in with relatively steep bank. As the
turn progresses, the bank angle is reduced gradually because the tailwind component is diminishing,
resulting in a decreasing groundspeed.

During and after the turn onto this leg (the equivalent of the base leg in a traffic pattern), the wind
will tend to drift the airplane away from the field boundary. To compensate for the drift, the amount
of turn will be more than 90°.

The rollout from this turn must be such that as the wings become level; the airplane is turned slightly
toward the field and into the wind to correct for drift. The airplane should again be the same distance
from the field boundary and at the same altitude, as on other legs. The base leg should be continued
until the upwind leg boundary is being approached. Once more the pilot should anticipate drift and
turning radius. Since drift correction was held on the base leg, it is necessary to turn less than 90° to
align the airplane parallel to the upwind leg boundary. This turn should be started with a medium
bank angle with a gradual reduction to a shallow bank as the turn progresses. The rollout should be
timed to assure paralleling the boundary of the field as the wings become level.

While the airplane is on the upwind leg, the next field boundary should be observed as it is being
approached, to plan the turn onto the crosswind leg. Since the wind is a headwind on this leg, it is
reducing the airplane’s groundspeed and during the turn onto the crosswind leg will try to drift the
airplane toward the field. For this reason, the roll-in to the turn must be slow and the bank relatively
shallow to counteract this effect. As the turn progresses, the headwind component decreases,
allowing the groundspeed to increase. Consequently, the bank angle and rate of turn is increased
gradually to assure that upon completion of the turn the crosswind ground track will continue the
same distance from the edge of the field. Completion of the turn with the wings level should be
accomplished at a point aligned with the upwind corner of the field.
Simultaneously, as the wings are rolled level, the proper drift correction is established with the airplane turned into the wind. This requires that the turn be less than a 90° change in heading. If the turn has been made properly, the field boundary will again appear to be one-fourth to one-half mile away. While on the crosswind leg, the wind correction angle should be adjusted as necessary to maintain a uniform distance from the field boundary. As the next field boundary is being approached, the pilot should plan the turn onto the downwind leg. Since a wind correction angle is being held into the wind and away from the field while on the crosswind leg, this next turn will require a turn of more than 90°. Since the crosswind will become a tailwind, causing the groundspeed to increase during this turn, the bank initially should be medium and progressively increased as the turn proceeds. To complete the turn, the rollout must be timed so that the wings become level at a point aligned with the crosswind corner of the field just as the longitudinal axis of the airplane again becomes parallel to the field boundary. The distance from the field boundary should be the same as from the other sides of the field.
Figure 6-5.—S-turns across a road.

Usually, drift should not be encountered on the upwind or the downwind leg, but it may be difficult to find a situation where the wind is blowing exactly parallel to the field boundaries. This would make it necessary to use a slight wind correction angle on all the legs. It is important to anticipate the turns to correct for groundspeed, drift, and turning radius. When the wind is behind the airplane, the turn must be faster and steeper; when it is ahead of the airplane, the turn must be slower and shallower. These same techniques apply while flying in airport traffic patterns.

**S-Turns Across a Road**

An S-turn across a road is a practice maneuver in which the airplane’s ground track describes semicircles of equal radii on each side of a selected straight line on the ground. [Figure 6-5] The straight line may be a road, fence, railroad, or section line that lies perpendicular to the wind, and should be of sufficient length for making a series of turns. A constant altitude should be maintained throughout the maneuver.

The objectives are to develop the ability to compensate for drift during turns, orient the flightpath with ground references, and divide the pilot’s attention. The maneuver consists of crossing the road at a 90° angle and immediately beginning a series of 180° turns of uniform radius in opposite directions, recrossing the road at a 90° angle just as each 180° turn is completed.

To accomplish a constant radius ground track requires a changing roll rate and angle of bank to establish the wind correction angle. Both will increase or decrease as groundspeed increases or decreases.

The bank must be steepest when beginning the turn on the downwind side of the road and must be shallowed gradually as the turn progresses from a downwind heading to an upwind heading. On the upwind side, the turn should be started with a relatively shallow bank and then gradually steepened as the airplane turns from an upwind heading to a downwind heading.

In this maneuver, the airplane should be rolled from one bank directly into the opposite just as the reference line on the ground is crossed.

Before starting the maneuver, a straight ground reference line or road that lies 90° to the direction of the wind should be selected, then the area checked to ensure that no obstructions or other aircraft are in the immediate vicinity. The road should be approached from the upwind side, at the selected
altitude on a downwind heading. When directly over the road, the first turn should be started immediately. With the airplane headed down wind, the groundspeed is greatest and the rate of departure from the road will be rapid; so the roll into the steep bank must be fairly rapid to attain the proper wind correction angle. This prevents the airplane from flying too far from the road and from establishing a ground track of excessive radius.

During the latter portion of the first 90° of turn when the airplane’s heading is changing from a downwind heading to a crosswind heading, the groundspeed becomes less and the rate of departure from the road decreases. The wind correction angle will be at the maximum when the airplane is headed directly crosswind.

After turning 90°, the airplane’s heading becomes more and more an upwind heading, the groundspeed will decrease, and the rate of closure with the road will become slower. If a constant steep bank were maintained, the airplane would turn too quickly for the slower rate of closure, and would be headed perpendicular to the road prematurely. Because of the decreasing groundspeed and rate of closure while approaching the upwind heading, it will be necessary to gradually shallow the bank during the remaining 90° of the semicircle, so that the wind correction angle is removed completely and the wings become level as the 180° turn is completed at the moment the road is reached.

At the instant the road is being crossed again, a turn in the opposite direction should be started. Since the airplane is still flying into the headwind, the groundspeed is relatively slow. Therefore, the turn will have to be started with a shallow bank so as to avoid an excessive rate of turn that would establish the maximum wind correction angle too soon. The degree of bank should be that which is necessary to attain the proper wind correction angle so the ground track describes an arc the same size as the one established on the downwind side. Since the airplane is turning from an upwind to a downwind heading, the groundspeed will increase and after turning 90°, the rate of closure with the road will increase rapidly. Consequently, the angle of bank and rate of turn must be progressively increased so that the airplane will have turned 180° at the time it reaches the road. Again, the rollout must be timed so the airplane is in straight-and-level flight directly over and perpendicular to the road.

Throughout the maneuver a constant altitude should be maintained, and the bank should be changing constantly to effect a true semicircular ground track.

Often there is a tendency to increase the bank too rapidly during the initial part of the turn on the upwind side, which will prevent the completion of the 180° turn before recrossing the road. This is apparent when the turn is not completed in time for the airplane to cross the road at a perpendicular angle. To avoid this error, the pilot must visualize the desired half circle ground track, and increase the bank during the early part of this turn. During the latter part of the turn, when approaching the road, the pilot must judge the closure rate properly and increase the bank accordingly, so as to cross the road perpendicular to it just as the rollout is completed.
**Turns Around a Point**

In this training maneuver, the airplane is flown in two or more complete circles of uniform radii or distance from a prominent ground reference point using a maximum bank of approximately 45° while maintaining a constant altitude. Its objective, as in other ground reference maneuvers, is to help the pilot develop the ability to subconsciously control the airplane while dividing attention between the flightpath and ground references and watching for other air traffic in the vicinity.

The factors and principles of drift correction that are involved in S-turns are also applicable in this maneuver. As in other ground track maneuvers, a constant radius around a point will, if any wind exists, require a constantly changing angle of bank and angles of wind correction. The closer the airplane is to a direct downwind heading where the groundspeed is greatest, the steeper the bank and the faster the rate of turn required to establish the proper wind correction angle. The more nearly it is to a direct upwind heading where the groundspeed is least, the shallower the bank and the slower the rate of turn required to establish the proper wind correction angle. It follows, then, that throughout the maneuver the bank and rate of turn must be gradually varied in proportion to the groundspeed.

The point selected for turns around a point should be prominent, easily distinguished by the pilot, and yet small enough to present precise reference. [Figure 6-6] Isolated trees, crossroads, or other similar small landmarks are usually suitable.

To enter turns around a point, the airplane should be flown on a downwind heading to one side of the selected point at a distance equal to the desired radius of turn.

When any significant wind exists, it will be necessary to roll into the initial bank at a rapid rate so that the steepest bank is attained abeam of the point when the airplane is headed directly down wind. By entering the maneuver while heading directly down wind, the steepest bank can be attained immediately. Thus, if a maximum bank of 45° is desired, the initial bank will be 45° if the airplane is at the correct distance from the point. Thereafter, the bank is shallowed gradually until the point is reached where the airplane is headed directly up wind. At this point, the bank should be gradually...
steepened until the steepest bank is again attained when heading down wind at the initial point of entry.

Just as S-turns require that the airplane be turned into the wind in addition to varying the bank, so do turns around a point. During the downwind half of the circle, the airplane’s nose is progressively turned toward the inside of the circle; during the upwind half, the nose is progressively turned toward the outside. The downwind half of the turn around the point may be compared to the downwind side of the S-turn across a road; the upwind half of the turn around a point may be compared to the upwind side of the S-turn across a road.

As the pilot becomes experienced in performing turns around a point and has a good understanding of the effects of wind drift and varying of the bank angle and wind correction angle as required, entry into the maneuver may be from any point. When entering this maneuver at any point, the radius of the turn should be carefully selected, taking into account the wind velocity and groundspeed so that an excessive bank is not required later on to maintain the proper ground track.

Figure 6-7.—Eights along a road.

Eights Along a Road

An eight along a road is a maneuver in which the ground track consists of two complete adjacent circles of equal radii on each side of a straight road or other reference line on the ground. The ground track resembles a figure 8. [Figure 6-7] Like the other ground reference maneuvers, its objective is to develop division of attention while compensating for drift, maintaining orientation with ground references, and maintaining a constant altitude. Although eights along a road may be performed with the wind blowing parallel to the road or directly across the road, for simplification purposes, only the latter situation is explained since the principles involved in either case are common. A reference line or road which is perpendicular to the wind should be selected and the airplane flown parallel to and directly above the road. Since the wind is blowing across the flightpath, the airplane will require some wind correction angle to stay directly above the road during the initial straight and level portion. Before starting the maneuver, the area should be checked to ensure clearance of obstructions and avoidance of other aircraft. Usually, the first turn should be made toward a downwind heading starting with a medium bank. Since the airplane will be turning more and more directly down wind, the groundspeed will be gradually increasing and the rate of departing the road
will tend to become faster. Thus, the bank and rate of turn is increased to establish a wind correction angle to keep the airplane from exceeding the desired distance from the road when 180° of change in direction is completed. The steepest bank is attained when the airplane is headed directly down wind. As the airplane completes 180° of change in direction, it will be flying parallel to and using a wind correction angle toward the road with the wind acting directly perpendicular to the ground track. At this point, the pilot should visualize the remaining 180° of ground track required to return to the same place over the road from which the maneuver started.

While the turn is continued toward an upwind heading, the wind will tend to keep the airplane from reaching the road, with a decrease in groundspeed and rate of closure. The rate of turn and wind correction angle is decreased proportionately so that the road will be reached just as the 360° turn is completed. To accomplish this, the bank is decreased so that when headed directly up wind, it will be at the shallowest angle. In the last 90° of the turn, the bank may be varied to correct any previous errors in judging the returning rate and closure rate. The rollout should be timed so that the airplane will be straight and level over the starting point, with enough drift correction to hold it over the road.

After momentarily flying straight and level along the road, the airplane is then rolled into a medium bank turn in the opposite direction to begin the circle on the upwind side of the road. The wind will still be decreasing the groundspeed and trying to drift the airplane back toward the road; therefore, the bank must be decreased slowly during the first 90° change in direction in order to reach the desired distance from the road and attain the proper wind correction angle when 180° change in direction has been completed.

As the remaining 180° of turn continues, the wind becomes more of a tailwind and increases the airplane’s groundspeed. This causes the rate of closure to become faster; consequently, the angle of bank and rate of turn is increased further to attain sufficient wind correction angle to keep the airplane from approaching the road too rapidly. The bank will be at its steepest angle when the airplane is headed directly down wind.

In the last 90° of the turn, the rate of turn should be reduced to bring the airplane over the starting point on the road. The rollout must be timed so the airplane will be straight and level, turned into the wind, and flying parallel to and over the road.

**Eights Across a Road**

This maneuver is a variation of eights along a road and involves the same principles and techniques. The primary difference is that at the completion of each loop of the figure eight, the airplane should cross an intersection of roads or a specific point on a straight road. [Figure 6-8] The loops should be across the road and the wind should be perpendicular to the road. Each time the road is crossed, the crossing angle should be the same and the wings of the airplane should be level. The eights also may be performed by rolling from one bank immediately to the other, directly over the road.

**Eights Around Pylons**

This training maneuver is an application of the same principles and techniques of correcting for wind drift as used in turns around a point and the same objectives as other ground track maneuvers. In this case, two points or pylons on the ground are used as references, and turns around each pylon are made in opposite directions to follow a ground track in the form of a figure 8. [Figure 6-9] The pattern involves flying down wind between the pylons and up wind outside of the pylons. It may include a short period of straight-and-level flight while proceeding diagonally from one pylon to the other.
The pylons selected should be on a line 90° to the direction of the wind and should be in an area away from communities, livestock, or groups of people, to avoid possible annoyance or hazards to others. The area selected should be clear of hazardous obstructions and other air traffic. Throughout the maneuver a constant altitude of at least 500 feet above the ground should be maintained.

The eight should be started with the airplane on a downwind heading when passing between the pylons. The distance between the pylons and the wind velocity will determine the initial angle of bank required to maintain a constant radius from the pylons during each turn. The steepest banks will be necessary just after each turn entry and just before the rollout from each turn where the airplane is headed down wind and the groundspeed is greatest; the shallowest banks will be when the airplane is headed directly up wind and the groundspeed is least.

The rate of bank change will depend on the wind velocity, the same as it does in S-turns and turns around a point, and the bank will be changing continuously during the turns. The adjustment of the bank angle should be gradual from the steepest bank to the shallowest bank as the airplane progressively heads into the wind, followed by a gradual increase until the steepest bank is again reached just prior to rollout. If the airplane is to proceed diagonally from one turn to the other, the rollout from each turn must be completed on the proper heading with sufficient wind correction angle to ensure that after brief straight-and-level flight, the airplane will arrive at the point where a turn of the same radius can be made around the other pylon. The straight-and-level flight segments must be tangent to both circular patterns.
Eights-on-Pylons (Pylon Eights)

The eights-on-pylons is an advanced training maneuver that provides practice in developing coordination skills while the pilot’s attention is directed at maintaining a pivotal position on a selected pylon.

This training maneuver also involves flying the airplane in circular paths, alternately left and right, in the form of a figure 8 around two selected points or pylons on the ground. In this case, no attempt is made to maintain a uniform distance from the pylon. Instead, the airplane is flown at such an altitude and airspeed that a line parallel to the airplane’s lateral axis, and extending from the pilot’s eye, appears to pivot on each of the pylons. [Figure 6-10] The altitude that is appropriate for the airplane being flown is called the pivotal altitude and is governed by the groundspeed. While not truly a ground track maneuver as were the preceding maneuvers, the objective is similar—to develop the ability to maneuver the airplane accurately while dividing one’s attention between the flightpath and the selected points on the ground.
In explaining the performance of eights-on-pylons, the term “wingtip” is frequently considered as being synonymous with the proper reference line, or pivot point on the airplane. This interpretation is not always correct. High-wing, low-wing, sweptwing, and taper-wing airplanes, as well as those with tandem or side-by-side seating, will all present different angles from the pilot’s eye to the wingtip. [Fig. 6-11] Therefore, in the correct performance of eights-on-pylons, as in other maneuvers requiring a lateral reference, the pilot should use a sighting reference line that, from eye level, parallels the lateral axis of the airplane.

The sighting point or line, while not necessarily on the wingtip itself, may be positioned in relation to the wingtip (ahead, behind, above, or below), but even then it will differ for each pilot, and from each seat in the airplane. This is especially true in tandem (fore and aft) seat airplanes. In side-by-side type airplanes, there will be very little variation in the sighting lines for different persons if those persons are seated so that the eyes of each are at approximately the same level.

An explanation of the pivotal altitude is also essential. There is a specific altitude at which, when the airplane turns at a given groundspeed, a projection of the sighting reference line to the selected point on the ground will appear to pivot on that point. Since different airplanes fly at different airspeeds, the groundspeed will be different. [Figure 6-12] Therefore, each airplane will have its own pivotal altitude. The pivotal altitude does not vary with the angle of bank being used unless the bank is steep enough to affect the groundspeed. A rule of thumb for estimating pivotal altitude in calm wind is to square the true airspeed and divide by 15 for miles per hour (MPH) or 11.3 for knots.

Figure 6-12.—Looking parallel to the lateral axis.
Distance from the pylon affects the angle of bank. At any altitude above that pivotal altitude, the projected reference line will appear to move rearward in a circular path in relation to the pylon. Conversely, when the airplane is below the pivotal altitude, the projected reference line will appear to move forward in a circular path.

To demonstrate this, the airplane is flown at normal cruising speed, and at an altitude estimated to be below the proper pivotal altitude, and then placed in a medium-banked turn. It will be seen that the projected reference line of sight appears to move forward along the ground as the airplane turns.

A climb is then made to an altitude well above the pivotal altitude, and when the airplane is again at normal cruising speed, it is placed in a medium-banked turn. At this higher altitude, the projected reference line of sight now appears to move backward across the ground in a direction opposite that of flight.

After the high altitude extreme has been demonstrated, the power is reduced, and a descent at cruising speed begun in a continuing medium bank around the pylon. The apparent backward travel of the projected reference line with respect to the pylon will slow down as altitude is lost, stop for an instant, then start to reverse itself, and would move forward if the descent were allowed to continue below the pivotal altitude.

The altitude at which the line of sight apparently ceased to move across the ground was the pivotal altitude. If the airplane descended below the pivotal altitude, power should be added to maintain airspeed while altitude is regained to the point at which the projected reference line moves neither backward nor forward but actually pivots on the pylon. In this way the pilot can determine the pivotal altitude of the airplane. [Figure 6-13]
Figure 6-13.—Determining proper pivotal altitude of the airplane.

The pivotal altitude is critical and will change with variations in groundspeed. Since the headings throughout the turns continually vary from directly down wind to directly up wind, the groundspeed will constantly change. This will result in the proper pivotal altitude varying slightly throughout the eight. Therefore, adjustment is made for this by climbing or descending, as necessary, to hold the reference line or point on the pylons. This change in altitude will be dependent on how much the wind affects the groundspeed.

Before beginning the maneuver, select two points on the ground along a line which lies 90° to the direction of the wind. The area in which the maneuver is to be performed should be checked for obstructions and any other air traffic, and it should be located where a disturbance to groups of people, livestock, or communities will not result.

The selection of proper pylons is of importance to good eight-on-pylons. They should be sufficiently prominent to be readily seen by the pilot when completing the turn around one pylon and heading for the next, and should be adequately spaced to provide time for planning the turns and yet not cause unnecessary straight-and-level flight between the pylons. Approximately 3 to 5 seconds of straight-and-level flight should be sufficient for checking the area properly before entering the next turn.

For uniformity, the eight is usually begun by flying diagonally crosswind between the pylons to a point down wind from the first pylon so that the first turn can be made into the wind.

As the airplane approaches a position where the pylon appears to be just ahead of the wingtip, the
turn should be started by lowering the upwind wing to place the pilot’s line of sight reference on the pylon. As the turn is continued, the line of sight reference can be held on the pylon by gradually increasing the bank. The reference line should appear to pivot on the pylon. As the airplane heads into the wind, the groundspeed decreases; consequently, the pivotal altitude is lower and the airplane must descend to hold the reference line on the pylon. As the turn progresses on the upwind side of the pylon, the wind becomes more of a crosswind and drifts the airplane closer to the pylon. Since a constant distance from the pylon is not required on this maneuver, no correction to counteract drifting should be applied. Therefore, with the airplane drifting closer to the pylon, the angle of bank is increased to hold the reference line on the pylon.

If the reference line appears to move ahead of the pylon, the pilot should increase altitude. If the reference line appears to move behind the pylon, the pilot should decrease altitude. Varying rudder pressure to yaw the airplane and force the wing and reference line forward or backward to the pylon is a dangerous technique and must not be attempted.

As the airplane turns toward a downwind heading, the rollout from the turn should be started to allow the airplane to proceed diagonally to a point on the downwind side of the second pylon. The rollout must be completed in the proper wind correction angle to correct for wind drift, so that the airplane will arrive at a point down wind from the second pylon the same distance it was from the first pylon at the beginning of the maneuver.

Upon reaching that point, a turn is started in the opposite direction by lowering the upwind wing to again place the pilot’s line of sight reference on the pylon. The turn is then continued just as in the turn around the first pylon but in the opposite direction.

The most common error in attempting to hold a pylon is incorrect use of the rudder. When the projection of the reference line moves forward with respect to the pylon, many pilots will tend to press the inside rudder to yaw the wing backward. When the reference line moves behind the pylon, they will press the outside rudder to yaw the wing forward. The rudder is to be used only as a coordination control.

**PERFORMANCE MANEUVERS**

Performance maneuvers are useful in developing a high degree of pilot skill. Although most of these maneuvers are not performed during everyday flying, they aid the pilot in analyzing the forces acting on the airplane and in developing a fine control touch, coordination, and division of attention for accurate and safe maneuvering of the airplane. Therefore, the pilot should acquire a thorough understanding of the factors involved and the techniques recommended.

**Steep Turns**

The objective of the maneuver is to develop smoothness, coordination, orientation, division of attention, and control techniques while executing high performance turns.

The steep turn maneuver consists of a turn in either direction, using a bank angle between 45 to 60°. This will cause an overbanking tendency during which maximum turning performance is attained and relatively high load factors are imposed. Because of the high load factors imposed, these turns should be performed at an airspeed does not exceed the airplane’s design that maneuvering speed (V_A). The principles of an ordinary steep turn apply, but as a practice maneuver the steep turns should be continued until 360° or 720° of turn have been completed. [Figure 6-14]

An airplane’s maximum turning performance is its fastest rate of turn and its shortest radius of turn,
that change with both airspeed and angle of bank. Each airplane’s turning performance is limited by the amount of power its engine is developing, its limit load factor (structural strength), and its aerodynamic characteristics.

The limiting load factor determines the maximum bank which can be maintained without stalling or exceeding the airplane’s structural limitations. In most small planes, the maximum bank has been found to be approximately 50 to 60°.

The pilot should realize the tremendous additional load that is imposed on an airplane as the bank is increased beyond 45°. During a coordinated turn with a 70° bank, a load factor of approximately 3-G’s is placed on the airplane’s structure. Most general aviation type airplanes are stressed for approximately 3.8-G’s.

Regardless of the airspeed or the type of airplanes involved, a given angle of bank in a turn, during which altitude is maintained will always produce the same load factor. Pilots must be aware that an additional load factor increases the stalling speed at a significant rate—stalling speed increases with the square root of the load factor. For example, a light plane that stalls at 60 knots in level flight will stall at nearly 85 knots in a 60° bank. The pilot’s understanding and observance of this fact is an indispensable safety precaution for the performance of all maneuvers requiring turns.

Before starting the steep turn, the pilot should ensure that the area is clear of other air traffic since the rate of turn will be quite rapid. After establishing the manufacturer’s recommended entry speed or the design maneuvering speed, the airplane should be smoothly rolled into a selected bank angle between 45 to 60°. As the turn is being established, back-elevator pressure should be smoothly increased to increase the angle of attack. This provides the additional wing lift required to compensate for the increasing load factor.

After the selected bank angle has been reached, the pilot will find that considerable force is required on the elevator control to hold the airplane in level flight—to maintain altitude. Because of this increase in the force applied to the elevators, the load factor increases rapidly as the bank is increased. Additional back-elevator pressure increases the angle of attack, which results in an increase in drag. Consequently, power must be added to maintain the entry altitude and airspeed.

Eventually, as the bank approaches the airplane’s maximum angle, the maximum performance or structural limit is being reached. If this limit is exceeded, the airplane will be subjected to excessive structural loads, and will lose altitude, or stall. The limit load factor must not be exceeded, to prevent structural damage.

During the turn, the pilot should not stare at any one object. To maintain altitude, as well as

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Figure 6-14.—Steep turns.
orientation, requires an awareness of the relative position of the nose, the horizon, the wings, and the amount of bank. The pilot who references the aircraft's turn by watching only the nose will have trouble holding altitude constant; on the other hand, the pilot who watches the nose, the horizon, and the wings can usually hold altitude within a few feet. If the altitude begins to increase, or decrease, relaxing or increasing the back-elevator pressure will be required as appropriate. This may also require a power adjustment to maintain the selected airspeed. A small increase or decrease of 1 to 3° of bank angle may be used to control small altitude deviations. All bank angle changes should be done with coordinated use of aileron and rudder.

The rollout from the turn should be timed so that the wings reach level flight when the airplane is exactly on the heading from which the maneuver was started. While the recovery is being made, back-elevator pressure is gradually released and power reduced, as necessary, to maintain the altitude and airspeed.

**Steep Spiral**

A steep spiral is nothing more than a constant gliding turn, during which a constant radius around a point on the ground is maintained similar to the maneuver, turns around a point. The radius should be such that the steepest bank will not exceed 60°. The objective of the maneuver is to improve pilot techniques for power-off turns, wind drift control, planning, orientation, and division of attention. This spiral is not only a valuable flight training maneuver, but it has practical application in providing a procedure for dissipating altitude while remaining over a selected spot in preparation for landing, especially for emergency forced landings.

Sufficient altitude must be obtained before starting this maneuver so that the spiral may be continued through a series of at least three 360° turns. [Figure 6-15] The maneuver should not be continued below 1,000 feet above the surface unless performing an emergency landing in conjunction with the spiral.

Operating the engine at idle speed for a prolonged period during the glide may result in excessive engine cooling or spark plug fouling. The engine should be cleared periodically by briefly advancing the throttle to normal cruise power, while adjusting the pitch attitude to maintain a constant airspeed. Preferably, this should be done while headed into the wind to minimize any variation in groundspeed and radius of turn.

Figure 6-15.—*Steep spiral.*

![Steep Spiral Illustration](image)

After the throttle is closed and gliding speed is established, a gliding spiral should be started and a turn of constant radius maintained around the selected spot on the ground. This will require correction for wind drift by steepening the bank on downwind headings and shallowing the bank on upwind headings, just as in the maneuver turns around a point.

During the descending spiral, the pilot must judge the direction and speed of the wind at different altitudes and make appropriate changes in the angle of bank to maintain a uniform radius.

A constant airspeed should also be maintained throughout the maneuver. Failure to hold the airspeed
constant will cause the radius of turn and necessary angle of bank to vary excessively. On the downwind side of the maneuver, the steeper the bank angle the lower the pitch attitude must be to maintain a given airspeed. Conversely, on the upwind side, as the bank angle becomes shallower, the pitch attitude must be raised to maintain the proper airspeed. This is necessary because the airspeed tends to change as the bank is changed from shallow to steep to shallow.

During practice of the maneuver, the pilot should execute three turns and roll out toward a definite object or on a specific heading. During the rollout, smoothness is essential, and the use of controls must be so coordinated that no increase or decrease of speed results when the straight glide is resumed.

**Chandelle**

The objective of this maneuver is to develop the pilot’s coordination, orientation, planning, and feel for maximum performance flight, and to develop positive control techniques at varying airspeeds and attitudes.

A chandelle is a climbing turn beginning from approximately straight-and-level flight, and ending at the completion of 180° of turn in a wings-level, nose-high attitude at the minimum controllable airspeed. [Figure 6-16] The maneuver demands that the maximum flight performance of the airplane be obtained; the airplane should gain the most altitude possible for a given degree of bank and power setting without stalling. Since numerous atmospheric variables beyond control of the pilot will affect the specific amount of altitude gained, the altitude gain is not a criterion of the quality of the maneuver.

![Figure 6-16.—Chandelle.](image)

Prior to starting a chandelle, the flaps and gear (if retractable) should be in the UP position, power set to cruise condition, and the airspace behind and above clear of other air traffic. The maneuver should be entered from straight and level and at any speed no greater than the maximum entry speed recommended by the manufacturer—in most cases not above the airplane’s design
maneuvering speed.

After the appropriate airspeed and power setting have been established, the chandelle is started by smoothly entering a coordinated turn with an angle of bank appropriate for the airplane being flown. Normally, this angle of bank should not exceed approximately 30°. After the appropriate bank is established, a climbing turn should be started by smoothly applying back-elevator pressure to increase the pitch attitude at a constant rate and to attain the highest pitch attitude as 90° of turn is completed. As the climb is initiated in airplanes with fixed-pitch propellers, full throttle may be applied, but is applied gradually so that the maximum allowable RPM is not exceeded. In airplanes with constant-speed propellers, power may be left at the normal cruise setting.

Once the bank has been established, the angle of bank should remain constant until 90° of turn is completed. Although the degree of bank is fixed during this climbing turn, it may appear to increase and, in fact, actually will tend to increase if allowed to do so as the maneuver continues.

When the turn has progressed 90° from the original heading, the pilot should begin rolling out of the bank at a constant rate while maintaining a constant-pitch attitude. Since the angle of bank will be decreasing during the rollout, the vertical component of lift will increase slightly. For this reason, it may be necessary to release a slight amount of back-elevator pressure in order to keep the nose of the airplane from rising higher.

As the wings are being leveled at the completion of 180° of turn, the pitch attitude should be noted by checking the outside references and the attitude indicator. This pitch attitude should be held momentarily while the airplane is at the minimum controllable airspeed. Then the pitch attitude may be gently reduced to return to straight-and-level cruise flight.

Since the airspeed is constantly decreasing throughout the maneuver, the effects of engine torque become more and more prominent. Therefore, right-rudder pressure is gradually increased to control yaw and maintain a constant rate of turn and to keep the airplane in coordinated flight. The pilot should maintain coordinated flight by the feel of pressures being applied on the controls and by the ball instrument of the turn-and-slip indicator. If coordinated flight is being maintained, the ball will remain in the center of the race.

To roll out of a left chandelle, the left aileron must be lowered to raise the left wing. This creates more drag than the aileron on the right wing, resulting in a tendency for the airplane to yaw to the left. With the low airspeed at this point, torque effect tries to make the airplane yaw to the left even more. Thus, there are two forces pulling the airplane’s nose to the left—aileron drag and torque. To maintain coordinated flight, considerable right-rudder pressure is required during the rollout to overcome the effects of aileron drag and torque.

In a chandelle to the right, when control pressure is applied to begin the rollout, the aileron on the right wing is lowered. This creates more drag on that wing and tends to make the airplane yaw to the right. At the same time, the effect of torque at the lower airspeed is causing the airplane’s nose to yaw to the left. Thus, aileron drag pulling the nose to the right and torque pulling to the left, tend to neutralize each other. If excessive left-rudder pressure is applied, the rollout will be uncoordinated.

The rollout to the left can usually be accomplished with very little left rudder, since the effects of aileron drag and torque tend to neutralize each other. Releasing some right rudder, which has been applied to correct for torque, will normally give the same effect as applying left-rudder pressure. When the wings become level and the ailerons are neutralized, the aileron drag disappears. Because
of the low airspeed and high power, the effects of torque become the more prominent force and must continue to be controlled with rudder pressure. A rollout to the left is accomplished mainly by applying aileron pressure. During the rollout, right-rudder pressure should be gradually released, and left rudder applied only as necessary to maintain coordination. Even when the wings are level and aileron pressure is released, right-rudder pressure must be held to counteract torque and hold the nose straight.

**Lazy Eight**

The objective of the lazy eight is to develop the pilot’s feel for varying control forces, and the ability to plan and remain oriented while maneuvering the airplane with positive, accurate control. It requires constantly changing control pressures necessitated by changing combinations of climbing and descending turns at varying airspeeds. This is a maneuver often used to develop and demonstrate the pilot’s mastery of the airplane in maximum performance flight situations.

This maneuver derives its name from the manner in which the extended longitudinal axis of the airplane is made to trace a flight pattern in the form of a figure 8 lying on its side (a lazy 8). [Figure 6-17]

A lazy eight consists of two 180° turns, in opposite directions, while making a climb and a descent in a symmetrical pattern during each of the turns. At no time throughout the lazy eight is the airplane flown straight and level; instead, it is rolled directly from one bank to the other with the wings level only at the moment the turn is reversed at the completion of each 180° change in heading.

As an aid to making symmetrical loops of the 8 during each turn, prominent reference points should be selected on the horizon. The reference points selected should be 45°, 90°, and 135° from the direction in which the maneuver is begun.

Prior to performing a lazy eight, the airspace behind and above should be clear of other air traffic. The maneuver should be entered from straight-and-level flight at normal cruise power and at the airspeed recommended by the manufacturer or at the airplane’s design maneuvering speed.

The maneuver is started from level flight with a gradual climbing turn in the direction of the 45° reference point. The climbing turn should be planned and controlled so that the maximum pitchup attitude is reached at the 45° point. The rate of rolling into the bank must be such as to prevent the rate of turn from becoming too rapid. As the pitch attitude is raised, the airspeed decreases, causing the rate of turn to increase. Since the bank also is being increased, it too causes the rate of turn to increase. Unless the maneuver is begun with a slow rate of roll, the combination of increasing pitch and increasing bank will cause the rate of turn to be so rapid that the 45° reference point will be reached before the highest pitch attitude is attained.

At the 45° point, the pitch attitude should be at maximum and the angle of bank continuing to increase. Also, at the 45° point, the pitch attitude should start to decrease slowly toward the horizon and the 90° reference point. Since the airspeed is still decreasing, right-rudder pressure will have to be applied to counteract torque.

As the airplane’s nose is being lowered toward the 90° reference point, the bank should continue to increase. Due to the decreasing airspeed, a slight amount of opposite aileron pressure may be required to prevent the bank from becoming too steep. When the airplane completes 90° of the turn,
the bank should be at the maximum angle (approximately 30°), the airspeed should be at its minimum (5 to 10 knots above stall speed), and the airplane pitch attitude should be passing through level flight. It is at this time that an imaginary line, extending from the pilot’s eye and parallel to the longitudinal axis of the airplane, passes through the 90° reference point.

Figure 6-17. Lazy eight.

Lazy eights normally should be performed with no more than approximately a 30° bank. Steeper banks may be used, but control touch and technique must be developed to a much higher degree than when the maneuver is performed with a shallower bank.

The pilot should not hesitate at this point but should continue to fly the airplane into a descending turn so that the airplane’s nose describes the same size loop below the horizon as it did above. As the pilot’s reference line passes through the 90° point, the bank should be decreased gradually, and the airplane’s nose allowed to continue lowering. When the airplane has turned 135°, the nose should be in its lowest pitch attitude. The airspeed will be increasing during this descending turn, so it will be necessary to gradually relax rudder and aileron pressure and to simultaneously raise the nose and roll the wings level. As this is being accomplished, the pilot should note the amount of turn remaining and adjust the rate of rollout and pitch change so that the wings become level and the original airspeed is attained in level flight just as the 180° point is reached. Upon returning to the starting altitude and the 180° point, a climbing turn should be started immediately in the opposite direction toward the selected reference points to complete the second half of the eight in the same manner as the first half.

Due to the decreasing airspeed, considerable right rudder pressure is gradually applied to counteract torque at the top of the eight in both the right and left turns. The pressure will be greatest at the point of lowest airspeed.

More right rudder pressure will be needed during the climbing turn to the right than in the turn to the left because more torque correction is needed to prevent yaw from decreasing the rate of turn. In the left climbing turn, the torque will tend to contribute to the turn; consequently, less rudder pressure is
needed. It will be noted that the controls are slightly crossed in the right climbing turn because of the need for left aileron pressure to prevent overbanking and right rudder to overcome torque.

The correct power setting for the lazy eight is that which will maintain the altitude for the maximum and minimum airspeeds used during the climbs and descents of the eight. Obviously, if excess power were used, the airplane would have gained altitude when the maneuver is completed, if insufficient power were used, altitude would have been lost.
CHAPTER 7 - AIRPORT TRAFFIC PATTERNS, APPROACHES, AND LANDINGS

INTRODUCTION

This chapter explains the methods and factors that affect safety and the flow of air traffic, approaches, and landings at airports. This chapter also discusses the traffic pattern, approaches, and landings for both normal and abnormal circumstances. This chapter also provides the recommended procedures for a proper pattern approach and landing, so that pilots may better understand the factors that will influence their judgment and performance.

AIRPORT TRAFFIC PATTERNS AND OPERATIONS

Just as roads and streets are needed in order to utilize automobiles, airports or airstrips are needed to utilize airplanes. Every flight begins and ends at an airport or other suitable landing field. For that reason, it is essential that the pilot learn the traffic rules, traffic procedures, and traffic pattern layouts that may be in use at various airports.

When an automobile is driven on congested city streets, it can be brought to a stop to give way to conflicting traffic; however, an airplane can only be slowed down. Consequently, specific traffic patterns and traffic control procedures have been established at designated airports. The traffic patterns provide specific routes for takeoffs, departures, arrivals, and landings. The exact nature of each airport traffic pattern is dependent on the runway in use, wind conditions, obstructions, and other factors.

Control towers and radar facilities provide a means of adjusting the flow of arriving and departing aircraft, and render assistance to pilots in busy terminal areas. Airport lighting and runway marking systems are used frequently to alert pilots to abnormal conditions and hazards, so arrivals and departures can be made safely.

Airports vary in complexity from small grass or sod strips to major terminals having many paved runways and taxiways. Regardless of the type of airport, the pilot must know and abide by the rules and general operating procedures applicable to the airport being used. These rules and procedures are based not only on logic or common sense, but also on courtesy, and their objective is to keep air traffic moving with maximum safety and efficiency. The use of any traffic pattern, service, or procedure does not alter the responsibility of pilots to see and avoid other aircraft.

Airport Traffic Patterns

To assure that air traffic flows into and out of an airport in an orderly manner, an airport traffic pattern is established appropriate to the local conditions, including the direction and placement of the pattern, the altitude to be flown, and the procedures for entering and leaving the pattern. Unless the airport displays approved visual markings indicating that turns should be made to the right, the pilot should make all turns in the pattern to the left.

When operating at an airport with an operating control tower, the pilot receives, by radio, a clearance to approach or depart, as well as pertinent information about the traffic pattern. If there is not a control tower, it is the pilot’s responsibility to determine the direction of the traffic pattern, to comply
with the appropriate traffic rules, and to display common courtesy toward other pilots operating in the area.

The pilot is not expected to have extensive knowledge of all traffic patterns at all airports, but if the pilot is familiar with the basic rectangular pattern, it will be easy to make proper approaches and departures from most airports, regardless of whether they have control towers. At airports with operating control towers, the tower operator may instruct pilots to enter the traffic pattern at any point or to make a straight-in approach without flying the usual rectangular pattern. Many other deviations are possible if the tower operator and the pilot work together in an effort to keep traffic moving smoothly. Jets or heavy airplanes will frequently be flying wider and/or higher patterns than lighter airplanes, and in many cases will make a straight-in approach for landing.

Figure 7-1.—Standard rectangular traffic pattern.

Compliance with the basic rectangular traffic pattern reduces the possibility of conflicts at airports without an operating control tower. It is imperative that the pilot form the habit of exercising constant vigilance in the vicinity of airports even though the air traffic appears to be light.

The standard rectangular traffic pattern is illustrated in Figure 7-1. The traffic pattern altitude is usually 1,000 feet above the elevation of the airport surface. The use of a common altitude at a given airport is the key factor in minimizing the risk of collisions at airports without operating control towers.

It is recommended that while operating in the traffic pattern at an airport without an operating control tower the pilot maintain an airspeed that conforms with the limits established by the manufacturer. In any case, the speed should be adjusted, when practicable, so that it is compatible with the speed of other airplanes in the pattern.

When entering the traffic pattern at an airport without an operating control tower, inbound pilots are expected to observe other aircraft already in the pattern and to conform to the traffic pattern in use. If other aircraft are not in the pattern, then traffic indicators on the ground and wind indicators must be checked to determine which runway and traffic pattern direction should be used. Many airports have L-shaped traffic pattern indicators displayed with a segmented circle adjacent to the runway. The short member of the L shows the direction in which the traffic pattern turns should be made when using the runway parallel to the long member. These indicators should be checked while at a distance well away from any pattern that might be in use, or while at a safe height well above generally used pattern altitudes. When the proper traffic pattern direction has been determined, the
pilot should then proceed to a point well clear of the pattern before descending to the pattern altitude.

When approaching an airport for landing, the traffic pattern should be entered at a 45° angle to the downwind leg, headed toward a point abeam of the midpoint of the runway to be used for landing. Arriving airplanes should be at the proper traffic pattern altitude before entering the pattern, and should stay clear of the traffic flow until established on the entry leg. Entries into traffic patterns while descending create specific collision hazards and should always be avoided.

The entry leg should be of sufficient length to provide a clear view of the entire traffic pattern, and to allow the pilot adequate time for planning the intended path in the pattern and the landing approach.

The downwind leg is a course flown parallel to the landing runway, but in a direction opposite to the intended landing direction. This leg should be approximately 1/2 to 1 mile out from the landing runway, and at the specified traffic pattern altitude. During this leg, the before landing check should be completed and the landing gear extended if retractable. Pattern altitude should be maintained until abeam the approach end of the landing runway. At this point, power should be reduced and a descent begun. The downwind leg continues past a point abeam the approach end of the runway to a point approximately 45° from the approach end of the runway, and a medium bank turn is made onto the base leg.

The base leg is the transitional part of the traffic pattern between the downwind leg and the final approach leg. Depending on the wind condition, it is established at a sufficient distance from the approach end of the landing runway to permit a gradual descent to the intended touchdown point. The ground track of the airplane while on the base leg should be perpendicular to the extended centerline of the landing runway, although the longitudinal axis of the airplane may not be aligned with the ground track when it is necessary to turn into the wind to counteract drift. While on the base leg, the pilot must ensure, before turning onto the final approach, that there is no danger of colliding with another aircraft that may be already on the final approach.

The final approach leg is a descending flightpath starting from the completion of the base-to-final turn and extending to the point of touchdown. This is probably the most important leg of the entire pattern, because here the pilot's judgment and procedures must be the sharpest to accurately control the airspeed and descent angle while approaching the intended touchdown point. The various aspects are thoroughly explained later in this chapter. As stipulated in Air Law procedures, aircraft while on final approach to land or while landing, have the right-of-way over other aircraft in flight or operating on the surface. When two or more aircraft are approaching an airport for the purpose of landing, the aircraft at the lower altitude has the right-of-way. Pilots should not take advantage of this rule to cut in front of another aircraft that is on final approach to land, or to overtake that aircraft.

The upwind leg is a course flown parallel to the landing runway, but in the same direction to the intended landing direction. The upwind leg continues past a point abeam of the departure end of the runway to where a medium bank 90° turn is made onto the crosswind leg.

The upwind leg is also the transitional part of the traffic pattern when on the final approach and a go-around is initiated and climb attitude is established. When a safe altitude is attained, the pilot should commence a shallow bank turn to the upwind side of the airport. This will allow better visibility of the runway for departing aircraft.

The departure leg of the rectangular pattern is a straight course aligned with, and leading from, the takeoff runway. This leg begins at the point the airplane leaves the ground and continues until the
90° turn onto the crosswind leg is started.

On the departure leg after takeoff, the pilot should continue climbing straight ahead until reaching a point beyond the departure end of the runway and within 300 feet of traffic pattern altitude or 500 feet above ground level (AGL). If leaving the pattern, the pilot should continue straight ahead, or depart by making a 45° left turn (right turn for a right-hand pattern).

The crosswind leg is the part of the rectangular pattern that is horizontally perpendicular to the extended centerline of the takeoff runway and is entered by making approximately a 90° turn from the upwind leg. On the crosswind leg, the airplane proceeds to the downwind leg position.

Since in most cases the takeoff is made into the wind, the wind will now be approximately perpendicular to the airplane’s flightpath. As a result, the airplane will have to be turned or headed slightly into the wind while on the crosswind leg to maintain a ground track that is perpendicular to the runway centerline extension.

Additional information on airport operations can be found in the Aeronautical Information Manual (AIM).

NORMAL APPROACH AND LANDING

A normal approach and landing involves the use of procedures for what is considered a normal situation; that is, when engine power is available, the wind is light or the final approach is made directly into the wind, the final approach path has no obstacles, and the landing surface is firm and of ample length to gradually bring the airplane to a stop. The selected landing point should be beyond the runway’s approach threshold but within the first one-third portion of the runway.

The factors involved and the procedures described for the normal approach and landing also have applications to the other-than-normal approaches and landings which are discussed later in this chapter. This being the case, the principles of normal operations are explained first and must be understood before proceeding to the more complex operations. So that the pilot may better understand the factors that will influence judgment and procedures, that last part of the approach pattern and the actual landing will be divided into five phases: the base leg, the final approach, the roundout, the touchdown, and the after-landing roll.

Base Leg

The placement of the base leg is one of the more important judgments made by the pilot in any landing approach. The pilot must accurately judge the altitude and distance from which a gradual descent will result in landing at the desired spot. The distance will depend on the altitude of the base leg, the effect of wind, and the amount of wing flaps used. When there is a strong wind on final approach or the flaps will be used to produce a steep angle of descent, the base leg must be positioned closer to the approach end of the runway than would be required with a light wind or no flaps. Normally, the landing gear should be extended and the before landing check completed prior to reaching the base leg.

After turning onto the base leg, the pilot should start the descent with reduced power and airspeed of approximately 1.4 \( V_{SO} \). \( V_{SO} \)—the stalling speed with power off, landing gears and flaps down.) For example, if \( V_{SO} \) is 60 knots, the speed should be 1.4 times 60, or 84 knots. Landing flaps may be partially lowered, if desired, at this time. Full flaps are not recommended until the final approach is established and the landing assured. Drift correction should be established and maintained to follow a ground track perpendicular to the extension of the centerline of the runway on which the landing is to
be made. Since the final approach and landing will normally be made into the wind, there will be somewhat of a crosswind during the base leg. This requires that the airplane be angled sufficiently into the wind to prevent drifting farther away from the intended landing spot.

The base leg should be continued to the point where a medium to shallow-banked turn will align the airplane's path directly with the centerline of the landing runway. This descending turn should be completed at a safe altitude that will be dependent upon the height of the terrain and any obstructions along the ground track. The turn to the final approach should also be sufficiently above the airport elevation to permit a final approach long enough for the pilot to accurately estimate the resultant point of touchdown, while maintaining the proper approach airspeed. This will require careful planning as to the starting point and the radius of the turn. Normally, it is recommended that the angle of bank not exceed a medium bank because the steeper the angle of bank, the higher the airspeed at which the airplane stalls. Since the base-to-final turn is made at a relatively low altitude, it is important that a stall not occur at this point. If an extremely steep bank is needed to prevent overshooting the proper final approach path, it is advisable to discontinue the approach, go around, and plan to start the turn earlier on the next approach rather than risk a hazardous situation.

**Final Approach**

After the base-to-final approach turn is completed, the longitudinal axis of the airplane should be aligned with the centerline of the runway or landing surface, so that drift (if any) will be recognized immediately. On a normal approach, with no wind drift, the longitudinal axis should be kept aligned with the runway centerline throughout the approach and landing. (The proper way to correct for a crosswind will be explained under the section, Crosswind Approach and Landing. For now, only an approach and landing where the wind is light or straight down the runway will be discussed.)

After aligning the airplane with the runway centerline, the final flap setting should be completed and the pitch attitude adjusted as required for the desired rate of descent. Slight adjustments in pitch and power may be necessary to maintain the descent attitude and the desired approach airspeed. In the absence of the manufacturer's recommended airspeed, a speed equal to 1.3 $V_{SO}$ should be used. If $V_{SO}$ is 60 knots, the speed should be 78 knots. When the pitch attitude and airspeed have been stabilized, the airplane should be retrimmed to relieve the pressures being held on the controls.

The descent angle should be controlled throughout the approach so that the airplane will land in the center of the first third of the runway. The descent angle is affected by all four fundamental forces that act on an airplane (lift, drag, thrust, and weight). If all the forces are constant, the descent angle will be constant in a no-wind condition. The pilot can control these forces by adjusting the airspeed, attitude, power, and drag (flaps or forward slip).

The wind also plays a prominent part in the gliding distance over the ground; naturally, the pilot does not have control over the wind but may correct for its effect on the airplane's descent by appropriate pitch and power adjustments.

Considering the factors that affect the descent angle on the final approach, for all practical purposes at a given pitch attitude there is only one power setting for one airspeed, one flap setting, and one wind condition. A change in any one of these variables will require an appropriate coordinated change in the other controllable variables. For example, if the pitch attitude is raised too high without an increase of power, the airplane will settle very rapidly and touch down short of the desired spot. For this reason, never try to stretch a glide by applying back-elevator pressure alone to reach the desired landing spot. This will shorten the gliding distance if power is not added simultaneously. The proper
angle of descent and airspeed should be maintained by coordinating pitch attitude changes and power changes. The objective of a good final approach is to descend at an angle and airspeed that will permit the airplane to reach the desired touchdown point at an airspeed which will result in minimum floating just before touchdown. To accomplish this, it is essential that both the descent angle and the airspeed be accurately controlled. Since on a normal approach the power setting is not fixed as in a power-off approach, the power should be adjusted, as necessary, to control the airspeed, and the pitch attitude adjusted simultaneously to control the descent angle or to attain the desired altitudes along the approach path. By lowering the nose and reducing power to keep approach airspeed constant, a descent at a higher rate can be made to correct for being too high in the approach. This is one reason for performing approaches with partial power; if the approach is too high, merely lower the nose and reduce the power. When the approach is too low, add power and raise the nose. On the other hand, if the approach is extremely high or low, it is advisable to execute a go-around. This procedure is explained later in this chapter.

Adjusting the descent through the use of the landing flaps may also vary the lift/drag factors. [Figures 7-2 and 7-3] When the flaps are lowered, the airspeed will decrease unless the power is increased or the pitch attitude lowered. After starting the final approach, the pilot must then estimate where the airplane will land through discerning judgment of the descent angle. If it appears that the airplane is going to overshoot or land slightly beyond the desired spot, more flaps may be used if not fully extended or the power reduced further, and the pitch attitude lowered. This will result in a steeper approach. If the spot is being undershot and a shallower approach is needed, the power and the pitch attitude should be increased to readjust the descent angle and the airspeed. Never retract the flaps to correct for undershooting since that will suddenly decrease the lift and cause the airplane to sink even more rapidly.

![Figure 7-2.—Effect of flaps on the landing point.](image)

![Figure 7-3.—Effect of flaps on the approach angle.](image)

The airplane must be retrimmed on the final approach to compensate for the change in aerodynamic forces. With the reduced power and with a slower airspeed, the airflow produces less lift on the wings and less downward force on the horizontal stabilizer, resulting in a significant nosedown tendency. The elevator must then be trimmed more nose up.

It will be found that the roundout, touchdown, and landing roll are much easier to accomplish when they are preceded by a proper final approach with precise control of airspeed, attitude, power, and
drag resulting in a stabilized descent angle.

Figure 7-4.—Changing angle of attack during roundout.

Estimating Height and Movement

During the approach, roundout, and touchdown vision is of prime importance. To provide a wide scope of vision and to foster good judgment of height and movement, the pilot’s head should assume a natural, straight-ahead position. The pilot’s visual focus should not be fixed on any one side or any one spot ahead of the airplane, but should be changing slowly from a point just over the airplane’s nose to the desired touchdown zone and back again, while maintaining a deliberate awareness of distance from either side of the runway within the pilot’s peripheral field of vision.

Accurate estimation of distance is, besides being a matter of practice, dependent upon how clearly objects are seen; it requires that the vision be focused properly in order that the important objects stand out as clearly as possible.

Speed blurs objects at close range. For example, most everyone has noted this in an automobile moving at high speed. Nearby objects seem to merge together in a blur, while objects farther away stand out clearly. The driver subconsciously focuses the eyes sufficiently far ahead of the automobile to see objects distinctly.

The distance at which the pilot’s vision is focused should be proportionate to the speed at which the airplane is traveling over the ground. Thus, as speed is reduced during the roundout, the distance ahead of the airplane at which it is possible to focus should be brought closer accordingly.

If the pilot attempts to focus on a reference that is too close or looks directly down, the reference will become blurred, and the reaction will be either too abrupt or too late. In this case, the pilot’s tendency will be to overcontrol, roundout high, and make full-stall drop-in landings. When the pilot focuses too far ahead, accuracy in judging the closeness of the ground is lost and the consequent reaction will be too slow since there will not appear to be a necessity for action, this will result in the airplane flying into the ground, nose first. The change of visual focus from a long distance to a short distance requires a definite time interval and even though the time is brief, the airplane’s speed during this interval is such that the airplane travels an appreciable distance, both forward and downward toward the ground.

If the focus is changed gradually, being brought progressively closer as speed is reduced, the time interval and the pilot’s reaction will be reduced, and the whole landing process smoothed out.

Roundout (Flare)

The roundout is a slow, smooth transition from a normal approach attitude to a landing attitude.
When the airplane, in a normal descent, approaches within what appears to be 10 to 20 feet above the ground, the roundout or flare should be started, and once started should be a continuous process until the airplane touches down on the ground.

As the airplane reaches a height above the ground where a timely change can be made into the proper landing attitude, back-elevator pressure should be gradually applied to slowly increase the pitch attitude and angle of attack. This will cause the airplane’s nose to gradually rise toward the desired landing attitude. The angle of attack should be increased at a rate that will allow the airplane to continue settling slowly as forward speed decreases.

When the angle of attack is increased, the lift is momentarily increased, which decreases the rate of descent. [Figure 7-4] Since power normally is reduced to idle during the roundout, the airspeed will also gradually decrease. This will cause lift to decrease again, and it must be controlled by raising the nose and further increasing the angle of attack. During the roundout, the airspeed is being decreased to touchdown speed while the lift is being controlled so the airplane will settle gently onto the landing surface. The roundout should be executed at a rate that the proper landing attitude and the proper touchdown airspeed are attained simultaneously just as the wheels contact the landing surface.

The rate at which the roundout is executed depends on the airplane’s height above the ground, the rate of descent, and the pitch attitude. A roundout started excessively high must be executed more slowly than one from a lower height to allow the airplane to descend to the ground while the proper landing attitude is being established. The rate of rounding out must also be proportionate to the rate of closure with the ground. When the airplane appears to be descending very slowly, the increase in pitch attitude must be made at a correspondingly slow rate.

The pitch attitude of the airplane in a full-flap approach is considerably lower than in a no-flap approach. To attain the proper landing attitude before touching down, the nose must travel through a greater pitch change when flaps are fully extended. Since the roundout is usually started at approximately the same height above the ground regardless of the degree of flaps used, the pitch attitude must be increased at a faster rate when full flaps are used; however, the roundout should still be executed at a rate proportionate to the airplane’s downward motion.

Once the actual process of rounding out is started, the elevator control should not be pushed forward. If too much back-elevator pressure has been exerted, this pressure should be either slightly relaxed or held constant, depending on the degree of the error. In some cases, it may be necessary to
advance the throttle slightly to prevent an excessive rate of sink, or a stall, all of which would result in a hard drop-in landing.

It is recommended that the pilot form the habit of keeping one hand on the throttle throughout the approach and landing, should a sudden and unexpected hazardous situation require an immediate application of power.

**Touchdown**

The touchdown is the gentle settling of the airplane onto the landing surface. The roundout and touchdown should be made with the engine idling, and the airplane at minimum controllable airspeed, so that the airplane will touch down on the main gear at approximately stalling speed. As the airplane settles, the proper landing attitude is attained by application of whatever back-elevator pressure is necessary.

Some pilots may try to force or fly the airplane onto the ground without establishing the proper landing attitude. The airplane should never be flown on the runway with excessive speed. It is paradoxical that the way to make an ideal landing is to try to hold the airplane’s wheels a few inches off the ground as long as possible with the elevators. In most cases, when the wheels are within 2 or 3 feet off the ground, the airplane will still be settling too fast for a gentle touchdown; therefore, this descent must be retarded by further back-elevator pressure. Since the airplane is already close to its stalling speed and is settling, this added back-elevator pressure will only slow up the settling instead of stopping it. At the same time, it will result in the airplane touching the ground in the proper landing attitude, and the main wheels touching down first so that little or no weight is on the nosewheel. [Figure 7-5]

After the main wheels make initial contact with the ground, back-elevator pressure should be held to maintain a positive angle of attack for aerodynamic braking, and to hold the nosewheel off the ground until the airplane decelerates. As the airplane’s momentum decreases, back-elevator pressure may be gradually relaxed to allow the nosewheel to gently settle onto the runway. This will permit steering with the nosewheel. At the same time, it will cause a low angle of attack and negative lift on
the wings to prevent floating or skipping, and will allow the full weight of the airplane to rest on the wheels for better braking action.

It is extremely important that the touchdown occur with the airplane’s longitudinal axis exactly parallel to the direction in which the airplane is moving along the runway. Failure to accomplish this imposes severe sideloads on the landing gear. To avoid these side stresses, the pilot should not allow the airplane to touch down while turned into the wind or drifting.

**Slips**

Basically there are two types of slips, a forward slip and a side slip. [Figure 7-6] A forward slip can be used to increase the airplane's descent angle without increasing airspeed. This could prove useful in making an emergency landing or in landing in an area with obstructions. A pilot should not use a slip to lose altitude because of poor planning.

To perform a forward slip, one wing should be lowered and at the same time opposite rudder applied to prevent the airplane from turning in the direction of the lowered wing. In this situation, the nose of the airplane will be pointed away from the runway, but the flightpath will be aligned with the runway. Once an acceptable altitude has been attained, the slip may be discontinued.

A sideslip is commonly used when performing a crosswind landing to counteract wind drift. A sideslip is the same as a forward slip except in a sideslip the airplane’s longitudinal axis remains parallel to the original flightpath and is aligned with the runway.

Before performing slips, the Airplane’s Flight Manual (AFM) and/or Pilot's Operating Handbook (POH) should be checked to see if any restrictions apply.

**Go-Arounds (Rejected Landings)**

Occasionally, it may be advisable for safety reasons to discontinue the landing approach and make another approach under more favorable conditions. Situations, such as air traffic control (ATC) requirements, extremely low base-to-final turns, overshooting turns, low final approaches, overtaking another airplane on the approach, wake turbulence from a preceding airplane, or unexpected appearance of hazards on the runway are examples of hazardous conditions that would demand initiating a go-around.

The need to discontinue an approach or landing may arise at any point in the approach or landing phase. Obviously, the most critical go-around landing is the one that is started when very close to the ground. Therefore, it is important that the earlier an unsafe situation is recognized, the safer the go-around/rejected landing will be.

A safe go-around can be accomplished if an early go-around decision is made, a sound plan is followed, and procedures are performed properly. When the decision is made to discontinue an approach, go around, or reject a landing, smoothly apply maximum allowable power, level the airplane’s wings and transition to a climb pitch attitude that will slow or stop the descent. After the descent has been stopped, landing flaps should be partially retracted and set as recommended by the manufacturer. In the absence of such a procedure, the flaps should be positioned to an approach or takeoff setting.

Caution must be used in retracting the flaps. Depending on the airplane’s altitude and airspeed, it may be wise to retract the flaps in small increments to allow time for the airplane to accelerate properly as they are being raised. A sudden and complete retraction of the flaps at a very low
airspeed could cause a loss of lift resulting in the airplane settling into the ground.

Unless otherwise specified in the airplane’s operating manual, it is recommended that the flaps be retracted (at least partially) before retracting the landing gear.

After a positive rate of climb is established, the landing gear can be retracted. It is important to accelerate to the best angle-of-climb speed, or greater, as quickly as possible and retract the remaining flaps. These speeds will provide for best climb performance.

Since the airplane has been trimmed for the approach (a low power and airspeed condition), application of maximum allowable power will require considerable control pressures to maintain a climb pitch attitude. This addition of power will tend to raise the airplane’s nose suddenly and veer to the left. Forward elevator pressure must be anticipated and applied to stop the nose at a proper climb pitch attitude. Right-rudder pressure also must be increased to counteract torque and P-factor, and to keep the nose from turning left. The pilot must hold the airplane at this proper pitch attitude, regardless of the amount of control pressure required. While holding the airplane in a takeoff or climb pitch attitude, the pilot should quickly retrim the airplane to relieve any adverse control pressures. Additional trim adjustment may be necessary to relieve control pressures as the airspeed increases. Later, more precise trim adjustments can be made when flight conditions are stabilized.

On airplanes that produce high control pressures when using maximum power on go-arounds, pilots should use caution when reaching for the flap handle to retract the flaps. Airplane control may become critical during this high workload phase.

It is advisable to retract the landing gear only after the initial or rough trim has been accomplished and when it is certain the airplane will remain airborne and not contact the surface. During the initial part of an extremely low go-around, the airplane may mush onto the runway and bounce. This situation is not particularly dangerous if takeoff pitch attitude and directional control is maintained. The airplane will be approaching safe flying speed rapidly and the higher power will cushion any secondary touchdown.

If the pitch attitude is increased excessively to prevent the airplane from settling onto the runway, this may cause the airplane to stall. This would be more likely if no trim correction is made and the flaps remain fully extended. Do not attempt to retract the landing gear until after some initial trim adjustment has been made and a positive rate of climb is established. After a positive rate of climb is established and the landing gear is retracted, the airplane should be allowed to accelerate to the best angle (V\textsubscript{x}) or to the best rate-of-climb speed (V\textsubscript{y}) before the final flap retraction is accomplished.

From this point on, the go-around procedure is similar with that for a normal climb after takeoff. If there is a conflict with departing traffic when at a safe altitude, it is recommended that a shallow banked turn be made away from the runway to keep the traffic in sight. The go-around should be completed parallel to the runway (upwind leg). This will provide better visibility and clearance from such traffic.

If operating at an airport with parallel runways, use caution when making a clearing turn away from the runway. It will be important to listen for traffic advisories and check for conflicting traffic on the parallel runway.

Tower communications and UNICOM advise should only be made up when the airplane is cleared and under positive control. Proceed on this upwind leg to again rejoin the traffic pattern crosswind leg for
another approach and landing.

**After-Landing Roll**

The landing process must never be considered complete until the airplane decelerates to the normal taxi speed during the landing roll or has been brought to a complete stop when clear of the landing area. Many accidents have occurred as a result of pilots abandoning their vigilance and positive control after getting the airplane on the ground.

The pilot must be alert for directional control difficulties immediately upon and after touchdown due to the ground friction on the wheels. The friction creates a pivot point on which a moment arm can act.

Loss of directional control may lead to an aggravated, uncontrolled, tight turn on the ground, or a ground loop. The combination of centrifugal force acting on the center of gravity (CG) and ground friction of the main wheels resisting it during the ground loop may cause the airplane to tip or lean enough for the outside wingtip to contact the ground. This may even impose a sideward force which could collapse the landing gear.

The rudder serves the same purpose on the ground as it does in the air—it controls the yawing of the airplane. The effectiveness of the rudder is dependent on the airflow, which depends on the speed of the airplane. As the speed decreases and the nosewheel has been lowered to the ground, the steerable nose provides more positive directional control.

The brakes of an airplane serve the same primary purpose as the brakes of an automobile—to reduce speed on the ground. In airplanes they may also be used as an aid in directional control when more positive control is required than could be obtained with rudder or nosewheel steering alone.

To use brakes, on an airplane equipped with toe brakes, the pilot should slide the toes or feet up from the rudder pedals to the brake pedals. If rudder pressure is being held at the time braking action is needed, that pressure should not be released as the feet or toes are being slid up to the brake pedals, because control may be lost before brakes can be applied.

During the ground roll, the airplane’s direction of movement can be changed by carefully applying pressure on one brake or uneven pressures on each brake in the desired direction. Caution must be exercised when applying brakes to avoid overcontrolling.

The ailerons serve the same purpose on the ground as they do in the air—they change the lift and drag components of the wings. During the after-landing roll, they should be used to keep the wings level in much the same way they were used in flight. If a wing starts to rise, aileron control should be applied toward that wing to lower it. The amount required will depend on speed because as the forward speed of the airplane decreases, the ailerons will become less effective. Procedures for using ailerons in crosswind conditions are explained further in this chapter, in the crosswind landings section.

After the airplane is on the ground, back-elevator pressure may be gradually relaxed to place normal weight on the nosewheel to aid in better steering.

If available runway permits, the speed of the airplane should be allowed to dissipate in a normal manner. Once the airplane has slowed sufficiently and has turned on to the taxiway and stopped, the pilot should retract the flaps and clean up the airplane. Too many accidents have occurred as a result of the pilot unintentionally operating the landing gear control and retracting the gear instead of the
flap control when the airplane was still rolling. The habit of positively identifying both of these controls, before actuating them, should be formed from the very beginning of flight training and continued in all future flying activities.

**Hydroplaning**

When there is a film of water on a runway, the airplane ground controllability and braking efficiency can be seriously affected. As the speed of the airplane and depth of the water increase, the water layer builds up an increasing resistance to displacement, resulting in the formation of a wedge of water beneath the tire. This progressively lifts the tire, decreasing the area in contact with the runway and causes the airplane to hydroplane on the film of water. In this condition, the tires no longer contribute to directional control and braking action is nil.

There are basically three types of hydroplaning they are dynamic, viscous, and reverted rubber.

**Dynamic**

Dynamic hydroplaning occurs when there is standing water on the runway surface. Water about one-tenth of an inch deep acts to lift the tire off the runway as explained above.

**Viscous**

Viscous hydroplaning is due to the viscous properties of water. A thin film of fluid no more than one-thousandth of an inch in depth cannot be penetrated by the tire and the tire rolls on top of this film. This can occur at a much lower speed than dynamic hydroplaning, but requires a smooth or smooth-acting surface.

**Reverted Rubber**

Reverted rubber hydroplaning requires a prolonged locked wheel skid, reverted rubber, and a wet runway surface. The reverted rubber acts as a seal between the tire and the runway, and delays water exit from the tire footprint area. The water heats and is converted to steam and the steam supports the tire off the runway.

Data obtained during hydroplaning tests have shown the minimum dynamic hydroplaning speed of a tire to be 8.6 times the square root of the tire pressure in pounds per square inch (PSI). For an airplane with a main tire pressure of 24 pounds, the calculated hydroplaning speed would be approximately 42 knots. It is important to note that the calculated speed referred to above is for the start of dynamic hydroplaning. Once hydroplaning has started, it may persist to a significantly slower speed depending on the type being experienced.

Pilots should always be alert to the possibility of standing water on a runway if it has recently rained. It is important to note that smooth surfaces and ungrooved runways do not promote drainage, as well as other runways. A pilot should always consider the type of runway, its width and length, as well as any other pertinent factors when the possibility of hydroplaning exists. If a landing is questionable, divert to another airport.

Lowering the nosewheel on a wet runway of adequate length will reduce angle of attack and stabilize the airplane during rollout. Therefore, it is important to have the nose tire tracking as soon as possible. Also retracting the flaps as soon as possible will improve traction; however, this should be done with caution, especially if operating a retractable gear airplane. Above all, use good judgment and follow recommendations provided by the manufacturer.
CROSSWIND APPROACH AND LANDING

Many runways or landing areas are such that landings must be made while the wind is blowing across rather than parallel to the landing direction. All pilots should be prepared to cope with these situations when they arise. The same basic principles and factors involved in a normal approach and landing apply to a crosswind approach and landing; therefore, only the additional procedures required for correcting for wind drift are discussed here.

Crosswind landings are a little more difficult to perform than crosswind takeoffs, mainly due to different problems involved in maintaining accurate control of the airplane while its speed is decreasing rather than increasing as on takeoff.

There are two usual methods of accomplishing a crosswind approach and landing—the crab method and the wing-low method. Although the crab method may be easier for the pilot to maintain during final approach, it requires a high degree of judgment and timing in removing the crab immediately prior to touchdown. The wing-low method is recommended in most cases although a combination of both methods may be used.

Crosswind Final Approach

The crab method is executed by establishing a heading (crab) toward the wind with the wings level so that the airplane’s ground track remains aligned with the centerline of the runway. This crab angle is maintained until just prior to touchdown, when the longitudinal axis of the airplane must be aligned with the runway to avoid sideward contact of the wheels with the runway. If a long final approach is being flown, the pilot may use the crab method until just before the roundout is started and then smoothly change to the wing-low method for the remainder of the landing.

The wing-low method will compensate for a crosswind from any angle, but more important, it enables the pilot to simultaneously keep the airplane’s ground track and longitudinal axis aligned with the runway centerline throughout the final approach, roundout, touchdown, and after-landing roll. This prevents the airplane from touching down in a sideward motion and imposing damaging side loads on the landing gear.

To use the wing-low method, the pilot aligns the airplane’s heading with the centerline of the runway, notes the rate and direction of drift, and then promptly applies drift correction by lowering the upwind wing. [Figure 7-7] The amount the wing must be lowered depends on the rate of drift. When the wing is lowered, the airplane will tend to turn in that direction. It is then necessary to simultaneously apply sufficient opposite rudder pressure to prevent the turn and keep the airplane’s longitudinal axis aligned with the runway. In other words, the drift is controlled with aileron, and the heading with rudder. The airplane will now be side slipping into the wind just enough that both the resultant flightpath and the ground track are aligned with the runway. If the crosswind diminishes, this crosswind correction is reduced accordingly, or the airplane will begin slipping away from the desired approach path.
To correct for strong crosswind, the slip into the wind is increased by lowering the upwind wing a considerable amount. As a consequence, this will result in a greater tendency of the airplane to turn. Since turning is not desired, considerable opposite rudder must be applied to keep the airplane’s longitudinal axis aligned with the runway. In some airplanes, there may not be sufficient rudder travel available to compensate for the strong turning tendency caused by the steep bank. If the required bank is such that full opposite rudder will not prevent a turn; the wind is too strong to safely land the airplane on that particular runway with those wind conditions. Since the airplane’s capability will be exceeded, it is imperative that the landing be made on a more favorable runway either at that airport or at an alternate airport. Flaps can and should be used during most approaches since they tend to have a stabilizing effect on the airplane. The degree to which flaps should be extended will vary with the airplane’s handling characteristics, as well as the wind velocity.

**Crosswind Roundout (Flare)**

Generally, the roundout can be made like a normal landing approach, but the application of a crosswind correction is continued as necessary to prevent drifting.

Since the airspeed decreases as the roundout progresses, the flight controls gradually become less effective. As a result, the crosswind correction being held will become inadequate. When using the wing-low method, it is necessary to gradually increase the deflection of the rudder and ailerons to maintain the proper amount of drift correction.

Do not level the wings; keep the upwind wing down throughout the roundout. If the wings are leveled, the airplane will begin drifting and the touchdown will occur while drifting. Remember, the primary objective is to land the airplane without subjecting it to any side loads that result from touching down while drifting.

**Crosswind Touchdown**

If the crab method of drift correction has been used throughout the final approach and roundout, the crab must be removed the instant before touchdown by applying rudder to align the airplane’s longitudinal axis with its direction of movement. This requires timely and accurate action. Failure to accomplish this will result in severe side loads being imposed on the landing gear.

If the wing-low method is used, the crosswind correction (aileron into the wind and opposite rudder) should be maintained throughout the roundout, and the touchdown made on the upwind main wheel.

During gusty or high-wind conditions, prompt adjustments must be made in the crosswind correction.
to assure that the airplane does not drift as the airplane touches down.

As the forward momentum decreases after initial contact, the weight of the airplane will cause the downwind main wheel to gradually settle onto the runway.

In those airplanes having nosewheel steering interconnected with the rudder, the nosewheel may not be aligned with the runway as the wheels touch down because opposite rudder is being held in the crosswind correction. To prevent swerving in the direction the nosewheel is offset, the corrective rudder pressure must be promptly relaxed just as the nosewheel touches down.

**Crosswind After-Landing Roll**

Particularly during the after-landing roll, special attention must be given to maintaining directional control by the use of rudder or nosewheel steering, while keeping the upwind wing from rising by the use of aileron.

When an airplane is airborne, it moves with the air mass in which it is flying regardless of the airplane’s heading and speed. When an airplane is on the ground, it is unable to move with the air mass (crosswind) because of the resistance created by ground friction on the wheels. Characteristically, an airplane has a greater profile or side area, behind the main landing gear than forward of it does. With the main wheels acting as a pivot point and the greater surface area exposed to the crosswind behind that pivot point, the airplane will tend to turn or weathervane into the wind.

Wind acting on an airplane during crosswind landings is the result of two factors. One is the natural wind, which acts in the direction the air mass is traveling, while the other is induced by the movement of the airplane and acts parallel to the direction of movement. Consequently, a crosswind has a headwind component acting along the airplane’s ground track and a crosswind component acting 90° to its track. The resultant or relative wind is somewhere between the two components. As the airplane’s forward speed decreases during the after-landing roll, the headwind component decreases and the relative wind has more of a crosswind component. The greater the crosswind component, the more difficult it is to prevent weathervaning.

While the airplane is decelerating during the after-landing roll, more and more aileron is applied to keep the upwind wing from rising. Since the airplane is slowing down, there is less airflow around the ailerons and they become less effective. At the same time, the relative wind is becoming more of a crosswind and exerting a greater lifting force on the upwind wing. When the airplane is coming to a stop, the aileron control must be held fully toward the wind.

**Turbulent Air Approach and Landing**

Power-on approaches at airspeed slightly above the normal approach speed should be used for landing in turbulent air. This provides for more positive control of the airplane when strong horizontal wind gusts, or up and down drafts, is experienced.

Like other power-on approaches (when the pilot can vary the amount of power), the angle of descent is controlled primarily by pitch adjustments, and the airspeed is controlled primarily by changes in power. A coordinated combination of both pitch and power adjustments is usually required. As in most other landing approaches, the proper approach attitude and airspeed require a minimum roundout and should result in little or no floating during the landing.

To maintain good control, the approach in turbulent air with gusty crosswind may require the use of partial wing flaps. With less than full flaps, the airplane will be in a higher pitch attitude. Thus, it will require less of a pitch change to establish the landing attitude, and the touchdown will be at a higher
airspeed to ensure more positive control. The speed should not be so excessive that the airplane will float past the desired landing area.

One procedure is to use the normal approach speed plus one-half of the wind gust factors. If the normal speed is 70 knots, and the wind gusts increase 15 knots, airspeed of 77 knots is appropriate. In any case, the airspeed and the amount of flaps should be as the airplane manufacturer recommends.

An adequate amount of power should be used to maintain the proper airspeed throughout the approach, and the throttle retarded to idling position only after the main wheels contact the landing surface. Care must be exercised in closing the throttle before the pilot is ready for touchdown. In this situation, the sudden or premature closing of the throttle may cause a sudden increase in the descent rate that could result in a hard landing.

Landings from power approaches in turbulence should be such that the touchdown is made with the airplane in approximately level flight attitude. The pitch attitude at touchdown should be only enough to prevent the nosewheel from contacting the surface before the main wheels have touched the surface.

**SHORT-FIELD APPROACH AND LANDING**

Short-field approaches and landings require the use of procedures for the approaches and landings at fields with a relatively short landing area or where an approach is made over obstacles that limit the available landing area. As in short-field takeoffs, it is one of the most critical of the maximum performance operations. It requires that the pilot fly the airplane at one of its crucial performance capabilities while close to the ground in order to safely land within confined areas. This low-speed type of power-on approach is closely related to the performance of flight at minimum controllable airspeeds.

To land within a short-field or a confined area, the pilot must have precise, positive control of the rate of descent and airspeed to produce an approach that will clear any obstacles, result in little or no floating during the roundout, and permit the airplane to be stopped in the shortest possible distance. [Figure 7-8]

**Figure 7-8.—** Short-field approach and landing.
The procedures for landing in a short-field or for landing approaches over 50-foot obstacles, as recommended in the AFM/POH, should be used. These procedures generally involve the use of full flaps, and the final approach started from an altitude of at least 500 feet higher than the touchdown area. In the absence of the manufacturer’s recommended approach speed, a speed of not more than 1.3 \( V_{SO} \) should be used—in an airplane that stalls at 60 knots with power off, and flaps and landing gear extended, the approach speed should not be higher than 78 knots. In gusty air, no more than one-half the gust factor should be added. An excessive amount of airspeed could result in a touchdown too far from the runway threshold or an after-landing roll that exceeds the available landing area.

After the landing gear and full flaps have been extended, the pilot should simultaneously adjust the power and the pitch attitude to establish and maintain the proper descent angle and airspeed.

Since short-field approaches are power-on approaches, the pitch attitude is adjusted, as necessary, to establish and maintain the desired rate or angle of descent, and power is adjusted to maintain the desired airspeed. A coordinated combination of both pitch and power adjustments is usually required. When this is done properly, very little change in the airplane’s pitch attitude is necessary to make corrections in the angle of descent, and only small power changes are needed to control the airspeed.

If it appears that the obstacle clearance is excessive and touchdown will occur well beyond the desired spot, leaving insufficient room to stop, power may be reduced while lowering the pitch attitude to increase the rate of descent. If it appears that the descent angle will not ensure safe clearance of obstacles, power should be increased while simultaneously raising the pitch attitude to decrease the rate of descent. Care must be taken to avoid an excessively low airspeed. If the speed is allowed to become too slow, an increase in pitch and application of full power may only result in a further rate of descent. This occurs when the angle of attack is so great and creating so much drag that the maximum available power is insufficient to overcome it. This is generally referred to as operating in the region of reverse command or operating on the back side of the power curve.

Because the final approach over obstacles is made at a steep approach angle and close to the airplane’s stalling speed, the initiation of the roundout or flare must be judged accurately to avoid flying into the ground, or stalling prematurely and sinking rapidly. A lack of floating during the flare, with sufficient control to touch down properly, is one verification that the approach speed was correct.

Touchdown should occur at the minimum controllable airspeed with the airplane in approximately the pitch attitude that will result in a power-off stall when the throttle is closed. Care must be exercised to avoid closing the throttle rapidly before the pilot is ready for touchdown, as closing the throttle may result in an immediate increase in the rate of descent and a hard landing.

Upon touchdown, the airplane should be held in this positive pitch attitude as long as the elevators remain effective. This will provide aerodynamic braking by the wings. Immediately upon touchdown, and closing the throttle, the brakes should be applied evenly and firmly to minimize the after-landing roll. The airplane should be stopped within the shortest possible distance consistent with safety.

**SOFT-FIELD APPROACH AND LANDING**

Landing on fields that are rough or have soft surfaces, such as snow, sand, mud, or tall grass requires unique procedures. When landing on such surfaces, the pilot must control the airplane in a manner that the wings support the weight of the airplane as long as practical, to minimize drag and stresses imposed on the landing gear by the rough or soft surface.
The approach for the soft-field landing is similar to the normal approach used for operating into long, firm landing areas. The major difference between the two is that, during the soft-field landing, the airplane is held 1 to 2 feet off the surface as long as possible to dissipate the forward speed sufficiently to allow the wheels to touch down gently at minimum speed.

The use of flaps during soft-field landings will aid in touching down at minimum speed and is recommended whenever practical. In low-wing airplanes, the flaps may suffer damage from mud, stones, or slush thrown up by the wheels. If flaps are used, it is generally inadvisable to retract them during the after-landing roll because the need for flap retraction is usually less important than the need for total concentration on maintaining full control of the airplane.

The final approach airspeed used for short-field landings is equally appropriate to soft-field landings, but there is no reason for a steep angle of descent unless obstacles are present in the approach path. Touchdown on a soft or rough field should be made at the lowest possible airspeed with the airplane in a nose-high pitch attitude.

In nosewheel-type airplanes, after the main wheels touch the surface, the pilot should hold sufficient back-elevator pressure to keep the nosewheel off the ground until it can no longer aerodynamically be held off the field surface. At this time, the pilot should gently lower the nosewheel to the surface. A slight addition of power during and immediately after touchdown usually will aid in easing the nosewheel down.

The use of brakes on a soft field is not needed and should be avoided as this may tend to impose a heavy load on the nose gear due to premature or hard contact with the landing surface, causing the nosewheel to dig in. The soft or rough surface itself will provide sufficient reduction in the airplane's forward speed. Often it will be found that upon landing on a very soft field, the pilot will need to increase power to keep the airplane moving and from becoming stuck in the soft surface.

POWER-OFF ACCURACY APPROACHES

Power-off accuracy approaches are approaches and landings made by gliding with the engine idling, through a specific pattern to a touchdown beyond and within 200 feet of a designated line or mark on the runway. The objective is to instill in the pilot the judgment and procedures necessary for accurately flying the airplane, without power, to a safe landing. The ability to estimate the distance an airplane will glide to a landing is the real basis of all power-off accuracy approaches and landings. This will largely determine the amount of maneuvering that may be done from a given altitude. In addition to the ability to estimate distance, it requires the ability to maintain the proper glide while maneuvering the airplane. With experience and practice, altitudes up to approximately 1,000 feet can be estimated with fair accuracy, while above this level the accuracy in judgment of height above the ground decreases, since all features tend to merge. The best aid in perfecting the ability to judge height above this altitude is through the indications of the altimeter and associating them with the general appearance of the earth.

The judgment of altitude in feet, hundreds of feet, or thousands of feet is not as important, as the ability to estimate gliding angle and its resultant distance. The pilot who knows the normal glide angle of the airplane can estimate with reasonable accuracy, the approximate spot along a given ground path at which the airplane will land, regardless of altitude. The pilot, who also has the ability to accurately estimate altitude, can judge how much maneuvering is possible during the glide, which is important to the choice of landing areas in an actual emergency.
The objective of a good final approach is to descend at an angle that will permit the airplane to reach the desired landing area, and at an airspeed that will result in minimum floating just before touchdown. To accomplish this, it is essential that both the descent angle and the airspeed be accurately controlled.

Unlike a normal approach when the power setting is variable, on a power-off approach the power is fixed at the idle setting. Pitch attitude rather than power is adjusted to control the airspeed. This will also change the glide or descent angle. By lowering the nose to keep the approach airspeed constant, the descent angle will become steeper. If the airspeed is too high, raise the nose, and when the airspeed is too low, lower the nose. If the pitch attitude is raised too high, the airplane will settle rapidly due to a slow airspeed and insufficient lift. For this reason, never try to stretch a glide to reach the desired landing spot.

Uniform approach patterns, such as the 90°, 180°, or 360° power-off approaches are described in the following sections. Practice in these approaches provides the pilot with a basis on which to develop judgment in gliding distance and in planning an approach.

The basic procedure in these approaches involves closing the throttle at a given altitude, and gliding to a key position. This position, like the pattern itself, must not be allowed to become the primary objective, it is merely a convenient point in the air from which the pilot can judge whether the glide will safely terminate at the desired spot. The selected key position should be one that is appropriate for the available altitude and the wind condition. From the key position, the pilot must constantly evaluate the situation.

It must be emphasized that, although accurate spot touchdowns are important, safe and properly executed approaches and landings are vital. The pilot must never sacrifice a good approach or landing just to land on the desired spot.

90° Power-Off Approach

The 90° power-off approach is made from a base leg and requires only a 90° turn onto the final approach. The approach path may be varied by positioning the base leg closer to or farther out from the approach end of the runway according to wind conditions. [Figure 7-9] The glide from the key...
position on the base leg through the 90° turn to the final approach is the final part of all accuracy landing maneuvers.

The 90° power-off approach usually begins from a rectangular pattern at approximately 1,000 feet above the ground or at normal traffic pattern altitude. The airplane should be flown onto a downwind leg at the same distance from the landing surface as in a normal traffic pattern. The before landing checklist should be completed on the downwind leg, including extension of the landing gear if the airplane is equipped with retractable gear.

Figure 7-10.— 90° power-off approach.

After a medium-banked turn onto the base leg is completed, the throttle should be retarded slightly and the airspeed allowed to decrease to the normal base-leg speed. [Figure 7-10] On the base leg, the airspeed, wind drift correction, and altitude should be maintained while proceeding to the 45° key position. At this position, the intended landing spot will appear to be on a 45° angle from the airplane’s nose.

The pilot can determine the strength and direction of the wind from the amount of crab necessary to hold the desired ground track on the base leg. This will help in planning the turn onto the final approach and in lowering the correct amount of flaps.

At the 45° key position, the throttle should be closed completely, the propeller control (if equipped) advanced to the full increase RPM position, and altitude maintained until the airspeed decreases to the manufacturer’s recommended glide speed. In the absence of a recommended speed, use 1.4 VSO. When this airspeed is attained, the nose should be lowered to maintain the gliding speed and the controls retrimmed.

The base-to-final turn should be planned and accomplished so that upon rolling out of the turn the airplane will be aligned with the runway centerline. When on final approach, the wing flaps are lowered and the pitch attitude adjusted, as necessary, to establish the proper descent angle and airspeed (1.3 VSO), then the controls retrimmed. Slight adjustments in pitch attitude or flaps setting may be necessary to control the glide angle and airspeed. However, NEVER TRY TO STRETCH THE GLIDE OR RETRACT THE FLAPS to reach the desired landing spot. The final approach may be made with or without the use of slips. After the final approach glide has been established, full attention is
then given to making a good, safe landing rather than concentrating on the selected landing spot.
The base leg position and the flap setting already determined the probability of landing on the spot.
In any event, it is better to execute a good landing 200 feet from the spot than to make a poor
landing precisely on the spot.

180° Power-Off Approach

The 180° power-off approach is executed by gliding with the power off from a given point on a
downwind leg to a preselected landing spot. [Figure 7-11] It is an extension of the principles involved
in the 90° power-off approach just described. Its objective is to further develop judgment in
estimating distances and glide ratios, in that the airplane is flown without power from a higher
altitude and through a 90° turn to reach the base leg position at a proper altitude for executing the
90° approach. The 180° power-off approach requires more planning and judgment than the 90°
power-off approach.

In the execution of 180° power-off approaches, the airplane is flown on a downwind heading parallel
to the landing runway and the landing gear extended (if retractable). The altitude from which this
type of approach should be started will vary with the type of airplane, but it should usually not
exceed 1,000 feet above the ground, except with large airplanes. Greater accuracy in judgment and
maneuvering is required at higher altitudes.

When abreast of or opposite the desired landing spot, the throttle should be closed and altitude
maintained while decelerating to the manufacturer’s recommended glide speed, or 1.4 VSO. The point
at which the throttle is closed is the downwind key position.

The turn from the downwind leg to the base leg should be a uniform turn with a medium or slightly
steeper bank. The degree of bank and amount of this initial turn will depend upon the glide angle of
the airplane and the velocity of the wind. Again, the base leg should be positioned as needed for the
altitude, or wind condition—position the base leg to conserve or dissipate altitude so as to reach the
desired landing spot.

The turn onto the base leg should be made at an altitude high enough and close enough to permit
the airplane to glide to what would normally be the base key position in a 90° power-off approach.
Although the key position is important, it must not be overemphasized nor considered as a fixed point on the ground. Many inexperienced pilots may gain a conception of it as a particular landmark, such as a tree, crossroad, or other visual reference, to be reached at a certain altitude. This will result in a mechanical conception and leave the pilot at a total loss any time such objects are not present. Both altitude and geographical location should be varied as much as is practical to eliminate any such conception. After reaching the base key position, the approach and landing are the same as in the 90° power-off approach.

360° Power-Off Approach

The 360° power-off approach is one in which the airplane glides through a 360° change of direction to the preselected landing spot. The entire pattern is designed to be circular, but the turn may be more shallow, steepened, or discontinued at any point to adjust the accuracy of the flightpath.

The 360° approach is started from a position over the approach end of the landing runway or slightly to the side of it, with the airplane headed in the proposed landing direction and the landing gear and flaps retracted. [Figure 7-12]

It is usually initiated from approximately 2,000 feet or more above the ground—where the wind may vary significantly from that at lower altitudes. This must be taken into account when maneuvering the airplane to a point from which a 90° or 180° power-off approach can be completed.

After the throttle is closed over the intended point of landing, the proper glide speed should immediately be established, and a medium banked turn made in the desired direction so as to arrive at the downwind key position opposite the intended landing spot. At or just beyond the downwind key position, the landing gear should be extended if the airplane is equipped with retractable gear. The altitude at the downwind key position should be approximately 1,000 to 1,200 feet above the ground.

After reaching that point, the turn should be continued to arrive at a base leg key position, at an
altitude of about 800 feet above the terrain. Flaps may be used at this position, as necessary, but full flaps should not be used until established on the final approach.

The angle of bank can be varied as needed throughout the pattern to correct for wind conditions and to align the airplane with the final approach. The turn-to-final should be completed at a minimum altitude of 300 feet above the terrain.
CHAPTER 8 - FAULTY APPROACHES AND LANDINGS

INTRODUCTION

This chapter discusses the factors contributing to faulty approaches and landings and describes the appropriate actions for making recoveries. A thorough knowledge of these factors is invaluable to the pilot in preventing landing accidents.

The explanations of approaches and landings up to this point have been devoted mainly to normal situations, in which the landings were ideally executed. In addition to occasional errors in judgment during some part of the approach and landing, numerous variables, such as traffic, wind shift, or wind gusts create situations requiring corrections or recoveries to assure a safe landing. Pilot skill in anticipation of, recognition of, and recovery from abnormal situations is equal in importance to normal approach and landing skills.

FINAL APPROACHES

Low Final Approach

When the base leg is too low, insufficient power is used, landing flaps are extended prematurely, or the velocity of the wind is misjudged, sufficient altitude may be lost, which will cause the airplane to be well below the proper final approach path. When it is realized the runway will not be reached unless appropriate action is taken, power must be applied immediately to maintain the airspeed while the pitch attitude is raised to increase lift and stop the descent. When the proper approach path has been intercepted, the correct approach attitude should be reestablished and the power reduced. DO NOT increase the pitch attitude without increasing the power, since the airplane will decelerate rapidly and may approach the critical angle of attack and stall. DO NOT retract the flaps, this will suddenly decrease lift and cause the airplane to sink more rapidly. If there is any doubt about the approach being safely completed, it is advisable to EXECUTE AN IMMEDIATE GO-AROUND.

High Final Approach

When the final approach is too high, lower the flaps as required. Further reduction in power may be necessary, and lowering the nose simultaneously to maintain approach airspeed and increase the rate of descent. When the proper approach path has been intercepted, adjust the power as required. When increasing the descent rate, care must be taken not to descend at an excessively high rate. If a high-sink rate is continued close to the surface, it may be difficult to slow to a proper rate prior to ground contact. A go-around should be initiated if the descent rate becomes excessive.

Slow Final Approach

When the airplane is flown at a slower-than-normal airspeed on the final approach, the pilot’s judgment of the rate of sink (descent) and the height of roundout will be difficult. During an excessively slow approach, the wing is operating near the critical angle of attack and, depending on the pitch attitude changes and control usage, the airplane may stall or sink rapidly, contacting the ground with a hard impact.

Whenever a slow-speed approach is noted, the pilot should apply power to accelerate the airplane and increase the lift to reduce the sink rate and to prevent a stall. This should be done while still at a high enough altitude to reestablish the correct approach airspeed and attitude. If too slow and too
low, it is best to EXECUTE A GO-AROUND.

**Use of Power**

Power can be used effectively during the approach and roundout to compensate for errors in judgment. Power can be added to accelerate the airplane to increase lift without increasing the angle of attack; thus, the descent can be slowed to an acceptable rate. If the proper landing attitude has been attained and the airplane is only slightly high, the landing attitude should be held constant and sufficient power applied to help ease the airplane onto the ground. After the airplane has touched down, it will be necessary to close the throttle so the additional thrust and lift will be removed and the airplane will stay on the ground.

**ROUNDOUT (FLARE)**

**High Roundout**

Sometimes when the airplane appears to temporarily stop moving downward, the roundout has been made too rapidly and the airplane is flying level, too high above the runway. Continuing the roundout would further reduce the airspeed, resulting in an increase in angle of attack to the critical angle. This would result in the airplane stalling and dropping hard onto the runway. To prevent this, the pitch attitude should be held constant until the airplane decelerates enough to again start descending. Then the roundout can be continued to establish the proper landing attitude. This procedure should only be used when there is adequate airspeed. It may be necessary to add a slight amount of power to keep the airspeed from decreasing excessively and to avoid losing lift too rapidly.

Although back-elevator pressure may be relaxed slightly, the nose should not be lowered any perceptible amount to make the airplane descend when fairly close to the runway unless some power is added momentarily. The momentary decrease in lift that would result from lowering the nose and decreasing the angle of attack may be so great that the airplane might contact the ground with the nose wheel first, which could collapse.

When the proper landing attitude is attained, the airplane is approaching a stall because the airspeed is decreasing and the critical angle of attack is being approached, even though the pitch attitude is no longer being increased. [Figure 8-1]

It is recommended that a GO-AROUND be executed any time it appears the landing is uncertain.

**Late or Rapid Roundout**

Starting the roundout too late or pulling the elevator control back too rapidly to prevent the airplane from touching down prematurely can impose a heavy load factor on the wing and cause an accelerated stall.

Suddenly increasing the angle of attack and stalling the airplane during a roundout is a dangerous
situation since it may cause the airplane to land extremely hard on the main landing gear, and then bounce back into the air. As the airplane contacts the ground, the tail will be forced down very rapidly by the back-elevator pressure and by inertia acting downward on the tail.

Recovery from this situation requires prompt and positive application of power prior to occurrence of the stall. This may be followed by a normal landing if sufficient runway is available—otherwise the pilot should EXECUTE A GO-AROUND immediately.

If the roundout is late, the nosewheel may strike the runway first, causing the nose to bounce upward. No attempt should be made to force the airplane back onto the ground; a GO-AROUND should be executed immediately.

**Floating During Roundout**

If the airspeed on final approach is excessive, it will usually result in the airplane floating. [Figure 8-2] Before touchdown can be made, the airplane may be well past the desired landing point and the available runway may be insufficient. When diving an airplane on final approach to land at the proper point, there will be an appreciable increase in airspeed. The proper touchdown attitude cannot be established without producing an excessive angle of attack and lift. This will cause the airplane to gain altitude or balloon.

![Figure 8-2.—Floating during roundout.](image)

Any time the airplane floats, judgment of speed, height, and rate of sink must be especially sharp. The pilot must smoothly and gradually adjust the pitch attitude as the airplane decelerates to touchdown speed and starts to settle, so the proper landing attitude is attained at the moment of touchdown. The slightest error in judgment and timing will result in either ballooning or bouncing.

Since prolonged floating utilizes considerable runway length, it should be avoided especially on short runways or in strong crosswinds. If a landing cannot be made on the first third of the runway, or the airplane drifts sideways, the pilot should EXECUTE A GO-AROUND.

**Ballooning During Roundout**

If the pilot misjudges the rate of sink during a landing and thinks the airplane is descending faster than it should, there is a tendency to increase the pitch attitude and angle of attack too rapidly. This not only stops the descent, but actually starts the airplane climbing. This climbing during the roundout is known as ballooning. [Figure 8-3] Ballooning can be dangerous because the height above the ground is increasing and the airplane may be rapidly approaching a stalled condition. The altitude gained in each instance will depend on the airspeed or the speed with which the pitch attitude is increased.

When ballooning is slight, a constant landing attitude should be held and the airplane allowed to gradually decelerate and settle onto the runway. Depending on the severity of ballooning, the use of throttle may be helpful in cushioning the landing. By adding power, thrust can be increased to keep the airspeed from decelerating too rapidly and the wings from suddenly losing lift, but throttle must be closed immediately after touchdown. Remember that torque will be created as power is applied;
therefore, it will be necessary to use rudder pressure to keep the airplane straight as it settles onto the runway.

When ballooning is excessive, it is best to EXECUTE A GO-AROUND IMMEDIATELY; DO NOT ATTEMPT TO SALVAGE THE LANDING. Power must be applied before the airplane enters a stalled condition.

The pilot must be extremely cautious of ballooning when there is a crosswind present because the crosswind correction may be inadvertently released or it may become inadequate. Because of the lower airspeed after ballooning, the crosswind affects the airplane more. Consequently, the wing will have to be lowered even further to compensate for the increased drift. It is imperative that the pilot makes certain that the appropriate wing is down and that directional control is maintained with opposite rudder. If there is any doubt, or the airplane starts to drift, EXECUTE A GO-AROUND.

Figure 8-3.—Balooning during roundout.

![Figure 8-3.—Balooning during roundout.](image)

Figure 8-4.—Bouncing during touchdown.

![Figure 8-4.—Bouncing during touchdown.](image)

**TOUCHDOWN**

**Bouncing During Touchdown**

When the airplane contacts the ground with a sharp impact as the result of an improper attitude or an excessive rate of sink, it tends to bounce back into the air. Though the airplane's tires and shock struts provide some springing action, the airplane does not bounce like a rubber ball. Instead, it rebounds into the air because the wing's angle of attack was abruptly increased, producing a sudden addition of lift. [Figure 8-4]

The abrupt change in angle of attack is the result of inertia instantly forcing the airplane’s tail downward when the main wheels contact the ground sharply. The severity of the bounce depends on the airspeed at the moment of contact and the degree to which the angle of attack or pitch attitude was increased.

Since a bounce occurs when the airplane makes contact with the ground before the proper touchdown attitude is attained, it is almost invariably accompanied by the application of excessive back-elevator pressure. This is usually the result of the pilot realizing too late that the airplane is not in the proper attitude and attempting to establish it just as the second touchdown occurs. The corrective action for a bounce is the same as for ballooning and similarly depends on its severity. When it is very slight and there is no extreme change in the airplane’s pitch attitude, a follow-up landing may be executed by applying sufficient power to cushion the subsequent touchdown, and
smoothly adjusting the pitch to the proper touchdown attitude.

In the event a very slight bounce is encountered while landing with a crosswind, crosswind correction must be maintained while the next touchdown is made. Remember that since the subsequent touchdown will be made at a slower airspeed, the upwind wing will have to be lowered even further to compensate for drift.

Extreme caution and alertness must be exercised any time a bounce occurs, but particularly when there is a crosswind. Inexperienced pilots will almost invariably release the crosswind correction. When one main wheel of the airplane strikes the runway, the other wheel will touch down immediately afterwards, and the wings will become level. Then, with no crosswind correction as the airplane bounces, the wind will cause the airplane to roll with the wind, thus exposing even more surface to the crosswind and drifting the airplane more rapidly.

When a bounce is severe, the safest procedure is to EXECUTE A GO-AROUND IMMEDIATELY. No attempt to salvage the landing should be made. Full power should be applied while simultaneously maintaining directional control, and lowering the nose to a safe climb attitude. The go-around procedure should be continued even though the airplane may descend and another bounce may be encountered. It would be extremely foolish to attempt a landing from a bad bounce since airspeed diminishes very rapidly in the nose-high attitude, and a stall may occur before a subsequent touchdown could be made.

**Porpoising**

In a bounced landing that is improperly recovered, the airplane comes in nose first setting off a series of motions that imitate the jumps and dives of a porpoise—hence the name. The problem is improper aircraft attitude at touchdown, sometimes caused by inattention, not knowing where the ground is, mistrimming or forcing the aircraft onto the runway.

Figure 8-5.—Drifting during touchdown.

Ground effect decreases elevator control effectiveness and increases the effort required to raise the nose. Not enough elevator or stabilator trim can result in a nose-low contact with the runway and a porpoise develops.

Porpoising can also be caused by improper airspeed control. Usually, if an approach is too fast, the airplane floats and the pilot tries to force it on the runway when the airplane still wants to fly. A gust of wind, a bump in the runway, or even a slight tug on the control wheel will send the aircraft aloft again.

The corrective action for a porpoise is the same as for a bounce and similarly depends on its severity. When it is very slight and there is no extreme change in the airplane’s pitch attitude, a follow-up landing may be executed by applying sufficient power to cushion the subsequent touchdown, and
smoothly adjusting the pitch to the proper touchdown attitude. When a porpoise is severe, the safest procedure is to EXECUTE A GO-AROUND IMMEDIATELY. No attempt to salvage the landing should be made. Full power should be applied while simultaneously maintaining directional control, and lowering the nose to a safe climb attitude.

**Wheelbarrowing**

When a pilot permits the aircraft weight to become concentrated about the nosewheel during the takeoff or landing roll, a condition known as wheelbarrowing will occur. Wheelbarrowing may cause loss of directional control during the landing roll because braking action is ineffective, and the airplane tends to swerve or pivot on the nosewheel, particularly in crosswind conditions. One of the most common causes of wheelbarrowing during the landing roll is a simultaneous touchdown of the main and nosewheel with excessive speed followed by application of forward pressure on the elevator control. Usually, the situation can be corrected by smoothly applying back-elevator pressure. However, if wheelbarrowing is encountered and runway and other conditions permit, it may be advisable to promptly initiate a go-around. Wheelbarrowing will not occur if the pilot achieves and maintains the correct landing attitude, touches down at the proper speed, and gently lowers the nosewheel while losing speed on rollout. If the pilot decides to stay on the ground rather than attempt a go-around or if he or she should lose directional control, then close the throttle, and smoothly but firmly rotate to the landing attitude. Raise the flaps to reduce lift and to increase the load on the main wheels for better braking action.

**Hard Landing**

When the airplane contacts the ground during landings, its vertical speed is instantly reduced to zero. Unless provisions are made to slow this vertical speed and cushion the impact of touchdown, the force of contact with the ground may be so great it could cause structural damage to the airplane.

The purpose of pneumatic tires, shock absorbing landing gears, and other devices is to cushion the impact and to increase the time in which the airplane's vertical descent is stopped. The importance of this cushion may be understood from the computation that a 6-inch free fall on landing is roughly equal to a 340-foot-per-minute descent. Within a fraction of a second, the airplane must be slowed from this rate of vertical descent to zero, without damage.

During this time, the landing gear together with some aid from the lift of the wings must supply whatever force is needed to counteract the force of the airplane's inertia and weight. The lift decreases rapidly as the airplane's forward speed is decreased, and the force on the landing gear increases by the impact of touchdown. When the descent stops, the lift will be practically zero, leaving the landing gear alone to carry both the airplane's weight and inertia force. The load imposed at the instant of touchdown may easily be three or four times the actual weight of the airplane depending on the severity of contact.

**Touchdown in a Drift or Crab**

At times the pilot may correct for wind drift by crabbing on the final approach. If the roundout and touchdown are made while the airplane is drifting or in a crab, it will contact the ground while moving sideways. This will impose extreme side loads on the landing gear, and if severe enough, may cause structural failure.

The most effective method to prevent drift in primary training aircraft is the wing-low method. This technique keeps the longitudinal axis of the airplane aligned with both the runway and the direction of motion throughout the approach and touchdown.
There are three factors that will cause the longitudinal axis and the direction of motion to be misaligned during touchdown: drifting, crabbing, or a combination of both.

If the pilot has not taken adequate corrective action to avoid drift during a crosswind landing, the main wheels’ tire tread offers resistance to the airplane’s sideward movement in respect to the ground. Consequently, any sidewise velocity of the airplane is abruptly decelerated, with the result that the inertia force is as shown in Figure 8-5. This creates a moment around the main wheel when it contacts the ground, tending to overturn or tip the airplane. If the windward wingtip is raised by the action of this moment, all the weight and shock of landing will be borne by one main wheel. This could cause structural damage.

Not only are the same factors present that are attempting to raise a wing, but the crosswind is also acting on the fuselage surface behind the main wheels, tending to yaw (weathervane) the airplane into the wind. This often results in a ground loop.

**Ground Loop**

A ground loop is an uncontrolled turn during ground operation that may occur while taxiing or taking off, but especially during the after-landing roll. Drift or weathervaning does not always cause a ground loop although these things may cause the initial swerve. Careless use of the rudder, an uneven ground surface, or a soft spot that retards one main wheel of the airplane may also cause a swerve. In any case, the initial swerve tends to make the airplane ground loop, whether it is a tailwheel-type or nosewheel-type. [Figure 8-6]

![Figure 8-6.—Start of a ground loop.](image)

Nose-wheel type airplanes are somewhat less prone to ground loop. Since the center of gravity (CG) is located forward of the main landing gear on these airplanes, any time a swerve develops, centrifugal force acting on the CG will tend to stop the swerving action.

If the airplane touches down while drifting or in a crab, the pilot should apply aileron toward the high wing and stop the swerve with the rudder. Brakes should be used to correct for turns or swerves only when the rudder is inadequate. The pilot must exercise caution when applying corrective brake action...
because it is very easy to overcontrol and aggravate the situation.

If brakes are used, sufficient brake should be applied on the low-wing wheel (outside of the turn) to stop the swerve. When the wings are approximately level, the new direction must be maintained until the airplane has slowed to taxi speed or has stopped.

**Wing Rising After Touchdown**

When landing in a crosswind, there may be instances when a wing will rise during the after-landing roll. This may occur whether or not there is a loss of directional control, depending on the amount of crosswind and the degree of corrective action.

Any time an airplane is rolling on the ground in a crosswind condition, the upwind wing is receiving a greater force from the wind than the downwind wing. This causes a lift differential. Also, as the upwind wing rises, there is an increase in the angle of attack, which increases lift on the upwind wing, rolling the aircraft down wind.

When the effects of these two factors are great enough, the upwind wing may rise even though directional control is maintained. If no correction is applied, it is possible that the upwind wing will rise sufficiently to cause the downwind wing to strike the ground.

In the event a wing starts to rise during the landing roll, the pilot should immediately apply more aileron pressure toward the high wing and continue to maintain direction. The sooner the aileron control is applied, the more effective it will be. The further a wing is allowed to rise before taking corrective action, the more airplane surface is exposed to the force of the crosswind. This diminishes the effectiveness of the aileron.
CHAPTER 9 - FLIGHT BY REFERENCE TO INSTRUMENTS

INTRODUCTION

This chapter provides guidance in developing the ability to maneuver the airplane for limited periods by reference to flight instruments and in following instructions from Air Traffic Control (ATC), when outside visual references are lost due to flight into instrument meteorological conditions (IMC). In an emergency situation, this ability could save the pilot’s life and those of the passengers, but intentional ventures into even marginal weather might eventually end in a serious accident.

BASIC INSTRUMENT TRAINING

During basic instrument training, pilots must understand that emergency use of flight instruments does not prepare them for unrestricted operations in instrument weather conditions. It is intended for emergency use only. Only those trained and certified as instrument pilots should attempt intentional flight in such conditions. Persons interested in pursuing a comprehensive instrument flying program should study the material in AC 61-27, Instrument Flying Handbook, and other pertinent publications, and complete a suitable instrument flying training course under the guidance of a certificated instrument flight instructor.

Accident investigations reveal that, as a related factor, weather continues to be cited more frequently than any other in general aviation accidents. The data also shows that weather-involved accidents are more likely to result in fatal injury than accidents not involving weather. Low ceilings, rain, and fog continue to head the list in the fatal, weather-involved general aviation accidents. The pilot involvement in this type of accident is usually the result of inadequate preflight preparation and/or planning, continued visual flight rules (VFR) flight into adverse weather conditions, and attempted operation beyond the pilot’s experience/ability level. In far too many cases, it was determined that the pilot did not obtain a preflight weather briefing. It appears logical to assume that if an adequate preflight briefing had been obtained, unexpected weather conditions would not have been encountered and many of the accidents would not have occurred.

All pilots should be somewhat conservative in judging their own capabilities and should use every means available to avoid weather situations that overtax one’s ability.

If inadvertently caught in poor weather conditions, the VFR pilot should, in addition to maintaining control of the airplane, notify the nearest Federal Aviation Administration (JAA) facility by radio, and follow their instructions. Calmness, patience, and compliance with those instructions represent the best chance for survival.

The Senses During Instrument Flight

The only way a pilot can control an airplane safely in a low-visibility environment is by using and trusting flight instruments. The orientation senses are not designed to cope with flight when clouds, fog, haze, dust, darkness, or other phenomena obscure external visual references, unless visual reference is transferred to the flight instruments. When the visual sense is provided with reference points, such as the Earth’s horizon or the flight instruments, there usually is not a problem with airplane attitude control since the visual sense overrides the other senses.
It is in situations where visual references, such as the ground and horizon are obscured that trouble develops, especially for pilots who lack training, experience, and proficiency in instrument flight. The vestibular sense (motion sensing by the inner ear) in particular tends to confuse the pilot. Because of inertia, the sensory areas of the inner ear cannot detect slight changes in the attitude of the airplane, nor can they accurately sense attitude changes that occur at a uniform rate over a period of time. On the other hand, false sensations often are generated; leading the pilot to believe the attitude of the airplane has changed when, in fact, it has not. These false sensations result in the pilot experiencing spatial disorientation.

When a disoriented pilot actually does make a recovery from a turn, bank, climb, or descent, there is a very strong tendency to feel that the airplane has entered a turn, bank, climb, or descent in the opposite direction. These false sensations may lead to the well-known “graveyard spiral.”

All pilots should be aware of these illusions and their consequences. Flight instructors should provide each student with an opportunity to experience these sensations under controlled conditions.

**BASIC INSTRUMENT FLIGHT**

The use of an airplane equipped with flight instruments and an easy means of simulating instrument flight conditions, are needed for training in flight by reference to instruments. Instruction in attitude control by reference to instruments should be conducted with the use of all available instruments in the airplane. When an attitude indicator is provided, its use as the primary reference for the control of the attitude of the airplane should be emphasized.

From the beginning of instruction in maneuvering the airplane by reference to instruments, three important actions should be stressed. First, a person cannot feel control pressure changes with a tight grip on the controls. Relaxing and learning to control with the eyes and the brain instead of only the muscles usually takes considerable conscious effort.
Second, attitude changes should be smooth and small, yet with positive pressure. No attitude changes should be made unless the instruments show a need for change.

Third, with the airplane properly trimmed, all control pressure should be released momentarily when one becomes aware of tenseness. The airplane is inherently stable and, except in turbulent air, will maintain approximate straight-and-level flight if left alone.

It must be reemphasized that the following procedures are intended only for an emergency while extracting one’s self from an inadvertent entry into IMC. The main goal is not precision instrument flying; rather, it is to help the VFR pilot keep the airplane under adequate control until suitable visual references are regained.

**Straight-and-Level Flight**

To maintain straight-and-level flight, the pilot must keep the airplane’s wings level with the horizon. Any degree of bank (in coordinated flight) will result in a deviation from straight flight, and a change in the airplane’s heading. Using the attitude indicator, straight flight is simplified by merely keeping the wings of the representative airplane level with the representative or artificial horizon. [Figure 9-1] This is accomplished by applying the necessary coordinated aileron and rudder pressures.

The needle of a turn indicator or the representative wings on a turn coordinator will deflect whenever the airplane is turning and will be centered or level when the airplane is in straight flight. They also can be used to maintain straight flight by applying coordinated aileron and rudder pressures, as needed; to keep the needle centered or the turn coordinator’s airplane wings level.

Regardless of which of these instruments is being used, the heading indicator should be checked frequently to determine whether a straight flightpath is actually being maintained. This is particularly true when flying in turbulent air since every little gust may bank the airplane and make it turn.

**Pitch Attitude**

At the same time that straight flight is being maintained, the pilot must also control the pitch attitude to keep the airplane level—no gain or loss of altitude. This can be accomplished by referencing several instruments. They are the attitude indicator, altimeter, and vertical speed indicator (VSI).

The attitude indicator will show the airplane pitch attitude in relation to the horizon. The altimeter tells when a constant altitude is being maintained or if the flight altitude is changing. The VSI will indicate the rate at which altitude is changing. Either of these instruments shows the pilot whether a change in pitch attitude is needed and approximately how much. [Figure 9-1]

Level flight requires the airplane’s nose be raised or lowered in relation to the horizon. This can be done by reference to the attitude indicator, by applying elevator pressure to adjust the representative airplane in relation to the horizon bar. The application of elevator pressure should be very slight to prevent overcontrolling. It must be emphasized that turn coordinators provide NO PITCH INFORMATION even though they have an appearance similar to attitude indicators.

In lieu of using an attitude indicator, the VSI may be used. If the instrument shows a climb or descent, the pilot should apply only sufficient elevator pressure to start the pointer moving toward the zero indication, since there is a certain amount of lag in the indication. Trying to obtain an immediate zero indication usually results in overcontrolling. When the pointer stabilizes again, additional pressure, if needed, can be added in increments to get a zero indication and gradually stop the climb or descent. Only after the vertical speed is zero and the altimeter remains constant should
an attempt be made to return to the original altitude.

In the case of an airplane having neither attitude indicator nor VSI, the airspeed indicator can be used like the VSI to maintain level flight. Remember though that it, too, lags somewhat as a result of the time required for the airplane to accelerate and decelerate after a pitch change is made.

Pilots must be cautioned not to chase the pointers on the instruments when flight through turbulent air produces erratic movements.

**Descents**

When unexpected adverse weather is encountered by the VFR pilot, the most likely situation is being trapped in or above a broken or solid layer of clouds or haze, requiring that a descent be made to an altitude where the pilot can reestablish visual reference to the ground. Generally, the descent should be made in straight flight.

A descent can be made at a variety of airspeeds and vertical speeds by reducing power, adding drag (gear and flaps), and lowering the nose to a predetermined attitude. Before beginning the descent, it is recommended that first the descent airspeed and the desired heading are established while holding the wings level. In addition, the landing gear and flaps should be positioned, as appropriate, to help in maintaining the desired rate of descent, or a fast rate of descent, as desired. Establishing the desired configuration before starting the descent will permit a more stabilized descent and require less division of attention once the descent is started. Rather than attempting to maintain a specific rate of descent, it is recommended that only a constant airspeed be maintained.

The following method for entering a descent is effective either with or without an attitude indicator. First, the airspeed is reduced to the desired airspeed by reducing power while maintaining straight-and-level flight. When the descent speed is established, a further reduction in power is made, and simultaneously the nose is lowered to maintain a constant airspeed. [Figure 9-2] A rule of thumb would be 100 RPM or 1 inch of manifold pressure reduction in power for each 100 feet per minute (FPM) rate of descent desired. The power should remain at a fixed (constant) setting and deviations in airspeed corrected by making pitch changes. Rapid throttle movements to control airspeed only add to the pilot’s workload.
If an attitude indicator is available, the pitch attitude can be adjusted by reference to the representative airplane and the artificial horizon, and then checking the airspeed indicator to determine if the attitude is correct. Using a half a bar width or one bar width below the artificial horizon will help establish a proper pitch attitude. Deviations from the desired airspeed should be corrected by adjusting the pitch attitude. If there is not an attitude indicator available and the airspeed is too high or too low, the pilot should apply sufficient elevator pressure to start the airspeed pointer moving toward the desired airspeed, since it takes a little time for the airspeed to stabilize. Trying to nail down the airspeed immediately will result in overcontrolling the airplane. Additional pressure can then be added, as necessary, to attain the desired airspeed.

In any case, the pilot should not be concerned with slight deviations in airspeed. The main objective is to descend at a safe airspeed, well above the stall, but not more than the airplane’s design maneuvering speed.

While descending, directional control should be maintained by referencing the directional instruments as described for straight-and-level flight. Pilots are cautioned against “chasing” the instrument pointers.

If any thought is given to the matter before starting the flight, the pilot will have a rough idea of the height of obstructions and terrain in the vicinity of the descent. Before starting the descent, a decision must be made regarding the minimum altitude to which the descent will be made.

**Climbs**

When adverse weather is encountered, a climb by referencing flight instruments is required primarily to assure clearance of obstructions or terrain. It may sometimes be advisable to climb to a clear area above a layer of fog, haze, or low clouds.

As in straight descents, the climb should be made at a constant airspeed—one that is well above the stall and results in a positive climb. The power setting and pitch attitude determines the airspeed.
The attitude indicator provides the greatest help in visualizing the pitch attitude. To enter a constant airspeed climb from cruising airspeed (the most likely entry speed), the nose of the representative airplane is raised in relation to the artificial horizon to the approximate climbing attitude, approximately a half to one bar width. [Figure 9-3] Only a small amount of back-elevator pressure should be added to initiate and maintain the climb attitude. The power setting may be advanced to climb power simultaneously with the pitch change, or, after the pitch change is established and the airspeed approaches the desired climb speed.

If there is not an attitude indicator available, the pilot should apply sufficient elevator pressure to start the airspeed pointer moving toward the desired climb airspeed and to cause the altimeter to show an upward trend. Because of inertia, speed will not be reduced immediately to the climb speed. The pilot must give the airspeed time to stabilize, then should apply whatever additional elevator pressure is needed to attain and maintain the desired airspeed. During the climb, the power should remain at a fixed (constant) setting and deviation in airspeed should be corrected by making pitch changes. Making throttle adjustments to correct for airspeed are unnecessary and burdensome.

As in descents during the emergency use of flight instruments, maintaining a precise airspeed is not important. The primary objective is to keep the airplane climbing—and not allow a stall to occur.

While climbing, the directional instruments should be scanned to detect any lapse of directional control just as in straight-and-level flight and straight descents. Unless a specific heading is required, slight deviations in headings, particularly in gusty air, should be of little concern—just keep the wings as level as possible.

**Turns to Headings**

When encountering adverse weather conditions, it is advisable for the pilot to use radio navigation aids, or to obtain directional guidance from ATC facilities. This usually requires that turns are made
and/or specific headings be maintained.

When making turns in adverse weather conditions, nothing is gained by maneuvering the airplane faster than the pilot’s ability to keep up with the changes that occur in the flight instrument indications. It is advisable to limit all turns to no more than a standard rate. A standard rate turn is one during which the heading changes 3° per second. On most turn indicators, this is shown when the needle is deflected one needle width; on turn coordinators, this is shown when the wingtip of the representative airplane is opposite the standard rate marker.

The rate at which a turn should be made is dictated generally by the amount of turn desired—a slow turn for small changes (less than 30°) in heading, a faster turn (up to a standard rate) for larger changes (more than 30°) in heading. [Figure 9-4]

Before starting the turn to any new heading, the pilot should hold the airplane straight and level and determine what direction the turn will be made. Then, based upon the amount of turn needed to reach the new heading, the rate or angle of bank should be decided upon. A rule of thumb would be to use 5° of bank for a 5° change of heading. When using the turn indicator, the needle should be deflected one needle width; when using a turn coordinator, the representative airplane’s wings should not be banked more than the standard marker.

Using the attitude indicator, the pilot should roll into the turn using coordinated aileron and rudder pressure in the direction of the desired turn to establish the desired bank angle. The amount and direction of the bank will be shown by the angle formed between the wings of the representative airplane and the line representing the horizon. If only a turn indicator is available, control pressures should be applied until the needle is deflected the desired amount; then the bank angle or turn needle deflection should be maintained until just before the desired heading is reached. Throughout the turn, the pitch attitude and altitude must be controlled as previously described.

While making turns for large heading changes, there may be a tendency to gain or lose altitude. If
the bank is controlled adequately, the altitude deviation usually will be only slight. The pilot should not be concerned about small deviations that can be corrected after the rollout; however, if the bank becomes too steep, altitude may be lost rapidly. In this case, the bank should become shallower rather than adding more back-elevator pressure.

As long as the airplane is in a coordinated bank, it will continue to turn. The rollout to a desired heading must be started before the heading is reached; therefore, it is important to refer to the heading indicator to determine the progress being made toward the desired heading, and when the rollout should be started.

At approximately 10° before reaching the desired heading (less lead for small heading changes) coordinated aileron and rudder pressures should be applied to roll the wings level and stop the turn. This is accomplished best by referencing the attitude indicator. If only a turn indicator or turn coordinator is available, the needle should be centered or the representative wings leveled as appropriate. Failure to roll out exactly on the desired heading should not cause great alarm—final corrections can be made after the airplane is in straight-and-level flight and the pilot is assured of having positive control. Remember that the airplane's nose will tend to rise as the wings are being returned to the level attitude. Sufficient forward elevator pressure must be applied to maintain a constant altitude.

Once again, the pilot is cautioned against chasing the pointers on the instruments. The pointers should be allowed to settle down and then make adjustments as needed.

Unusual Flight Attitudes

When outside visual references are inadequate or lost, the non-instrument rated pilot is apt to unintentionally let the airplane enter an unusual attitude. This involves an excessively nose-high attitude in which the airplane may be approaching a stall, or an extremely steep bank that may result in a steep downward spiral.

Since such attitudes are not intentional, they are often unexpected, and the reaction of an inexperienced or inadequately trained pilot is usually instinctive rather than intelligent and deliberate. However, with practice, the techniques for a rapid and safe recovery from these critical attitudes can be learned.

During instruction flights, the pilot should be instructed to take their hands and feet off the controls and to close their eyes. The instructor should then put the airplane into a critical attitude. The attitude may be an approach to a stall, or a well developed spiral dive. At this point, the pilot should be told to open their eyes, take the controls, and effect a recovery by referencing the flight instruments. IN ALL CASES, recoveries should be made to straight-and-level flight.

When an unusual attitude is noted on the flight instruments, the immediate problem is to recognize what the airplane is doing and decide how to return it to straight-and-level flight as quickly as possible. [Figure 9-5]

Nose-high attitudes are shown by the rate and direction of movement of the altimeter, vertical speed, and airspeed indicator, as well as the immediately recognizable indication on the attitude indicator. Nose-low attitudes are shown by the same instruments, but pointer movement is in the opposite direction.

Since many critical attitudes involve a rather steep bank, it is important to determine the direction of the turn. This can be accomplished best by referencing the attitude indicator. In the absence of an
attitude indicator, it will be necessary in the recovery to refer to the turn needle or turn coordinator to determine the direction of turn. Coordinated aileron and rudder pressure should be applied to level the wings of the representative airplane and center the turn needle.

Figure 9-5.—Unusual attitude.

Unlike the control applications in normal maneuvers, larger control movements in recoveries from critical attitudes may be necessary to bring the airplane under control. Nevertheless, such control applications must be smooth, positive, and prompt. To avoid aggravating the critical attitude with a control application in the wrong direction, the initial interpretation of the instruments must be accurate. Once the airplane is returned to approximately straight-and-level flight, control movements should be limited to small adjustments.

If the airspeed is decreasing rapidly and the altimeter indication is increasing faster than desired, the airplane's nose is too high. To prevent a stall from occurring, it is important to lower the nose as quickly as possible while simultaneously increasing power to prevent a further loss of airspeed. If an attitude indicator is available, the representative airplane should be lowered in relation to the artificial horizon by applying positive forward elevator pressure. If there is not an attitude indicator available, sufficient forward pressure should be applied to stop the movement of the pointers on the altimeter and airspeed indicators.
After the airplane has been returned to straight-and-level flight and the airspeed returns to normal, the power can be reduced to the normal setting.

If the airspeed is increasing rapidly and the altimeter indication is decreasing faster than desired, the airplane’s nose is too low. To prevent losing too much altitude or exceeding the speed limitations of the airplane, power must be reduced and the nose must be raised. With the higher-than-normal airspeed, it is vital to raise the nose smoothly to avoid overstressing the airplane. Back-elevator pressure must not be applied too suddenly. If the airplane is in a steep bank while descending, the wings should be leveled before attempting to raise the nose. Increasing back-elevator pressure before the wings are leveled will tend to increase the bank and only further aggravate the situation, leading to what is called a “graveyard spiral.” Furthermore, excessive G loads may be imposed, resulting in structural failure.

During initial training, students should be required to make the recovery from a nose-low spiral attitude by taking actions in the following sequence: (1) reduce the power; (2) level the wings; and (3) raise the nose. After proficiency is attained, all recovery actions may be taken simultaneously.

To level the wings, coordinated aileron and rudder pressure should be applied until the wings of the representative airplane are approximately parallel to the horizon bar on the attitude indicator. If only a turn indicator or turn coordinator is available, pressures should be applied to center the needle or to level the wings of the representative airplane as appropriate. Then smooth back-elevator pressure will be necessary to bring the representative airplane on the attitude indicator up to the horizon bar. Remember that the turn coordinator provides NO PITCH INFORMATION. If an attitude indicator is not available, sufficient back-elevator pressure must be applied to start the airspeed pointer moving toward a lower airspeed and to stop the movement of the altimeter pointer. After the airplane is in level flight and the airspeed returns to normal, the power can be adjusted to the normal setting. If considerable altitude has been lost, a gradual climb to the original altitude may be necessary to ensure safe terrain clearance.

**USE OF NAVIGATION SYSTEMS**

VFR flights should begin in good weather conditions. Most often it is after the flight progresses from good weather into deteriorating weather and the pilot continues in the hope that conditions will improve that the need for navigational help arises. Since the area from which the pilot came is where the good weather was, naturally it is advisable to turn around and head back to that area when deteriorating weather is first encountered. In most cases, there will be some type of navigation system available to help the pilot return to the good weather area. Unless hopelessly disoriented, the pilot should determine the location and transmitting frequency of a VOR or NDB (automatic direction finder (ADF)) or program a global positioning system (GPS) or long range navigation (LORAN) coordinate that can be used for guiding the airplane back to the better weather area.

When a VOR is chosen, the omnireceiver should be tuned to the assigned frequency of the selected VOR station. After the station is identified, the omnibearing selector (OBS) should be turned until the TO/FROM indicator shows TO and the course deviation needle is centered.

The OBS then will then indicate the magnetic course to fly directly to the station. The airplane should then be turned to the corresponding magnetic heading, and heading adjustments made as required to follow the course to the station.

If an NDB is used, the ADF receiver should be tuned to the frequency of the selected NDB and the
station positively identified. Then the airplane should be turned until the ADF pointer is on the nose position of the instrument. Keeping the pointer on this position will result in the airplane flying to the station although the ground track may be slightly curved due to a crosswind.

When using a GPS or LORAN, the pilot may program in an airport, VOR station, ADF station, or a known position to be in visual flying conditions. Using the direct key function, the unit will determine a direct route from the airplane’s present position to the fix. The unit will indicate the course to be flown to the fix. The airplane should then be turned to the corresponding heading, and adjustments to the heading made as required to follow the course to the station. The use of navigation systems when in unfavorable weather conditions requires additional division of attention while attempting to maintain control of the airplane. The pilot’s main concern is airplane control.

**USE OF RADAR SERVICES**

All pilots should be aware of radar equipped ATC facilities that provide assistance and navigation services, provided the airplane has appropriate communications equipment, is within radar coverage, and can be radar identified. This will allow radar facilities to vector a pilot to a nearby airport or to an area of good weather. The term “vector” simply means the heading to fly to reach a certain location. In this way, the pilot only needs to communicate and follow instructions while giving almost full attention to flying the airplane.

There are certain terms in the use of transponders that the pilot must understand. When instructed to SQUAWK a certain code (number), the pilot should first ensure that the transponder is set to the specified 4-digit number and turned ON (not standby). If told to IDENT, the pilot should press the button marked as such on the transponder. When told to SQUAWK MAYDAY (the emergency position), the transponder should be set to 7700. To obtain assistance by radio and apply it effectively, some preparation and training is necessary. All pilots should become familiar with the appropriate emergency procedures. The actual use of designated emergency radio frequencies for training exercises is not permitted, but JAA facilities are often able to provide practice orientation and radar guidance procedures using their regular communications frequencies.

When a pilot is in doubt about the airplane’s position, or feels apprehensive about the safety of the flight, there should be no hesitation to ask for help. That is the first means of declaring an emergency—use the radio transmitter and ask for help. If in actual distress, and help is needed immediately, the pilot should transmit the word MAYDAY several times before transmitting the emergency message. This will get immediate attention from all who hear. Since frequent communications may be necessary, it is recommended that the microphone be continually held in the hand. This will eliminate the need to take the eyes away from the flight instruments every time the microphone is removed from or replaced in its receptacle. After some practice, loosely holding the mike in one hand should not create any difficulty in using the flight controls. It is important though, that the mike button not be depressed accidentally, which would block the frequency and prevent the reception of further assistance. The initial request for assistance can be made on the regular communications frequency of the facility, or on the emergency frequency, 121.5 MHz, especially designated for such messages. The designated emergency very high frequency (VHF), 121.5 MHz, is available on radios installed in general aviation airplanes. This is usually the best frequency on which to transmit and receive because all radar facilities, control towers, and Flight Service Stations (FSS’s) monitor this frequency. Regardless of which frequency is used, it is essential that the pilot not change frequency unless instructed to do so by the operator or unless absolutely necessary.
If unable to establish communication with a radar facility, the pilot should call any control tower or FSS. The request will then be relayed immediately to the appropriate radar facility. The pilot must remember, though, that VHF transmissions follow line of sight; therefore, the higher the altitude, the better the chance of obtaining service. Effectiveness of radar service will depend on terrain conditions and altitude.

When the pilot request radar services, the operator will ask if the airplane is in VFR or instrument flight rules (IFR) weather conditions, the amount of fuel remaining, the altitude, and the heading. Also, the operator should be informed whether the pilot is instrument rated. If the airplane is in IFR weather conditions, the pilot will be informed of the minimum safe altitude and the current local altimeter setting will be provided.

When the airplane’s position has been determined, the radar operator will specify the direction to turn and the magnetic heading to be flown. (i.e., TURN LEFT, HEADING ZERO ONE ZERO, FOR RADAR VECTORS TO LENAWEE COUNTY AIRPORT, and REPORT AIRPORT IN SIGHT.)

Pilots should understand clearly that authorization to proceed in accordance with such radar navigational assistance does not constitute authorization for the pilot to violate the Code of Air Law Regulations.

To avoid possible hazards resulting from being vectored into IFR conditions, a VFR pilot in difficulty should keep the controller advised of the weather conditions the airplane is operating in and along the course ahead.

If the airplane has already encountered IFR conditions, the controller will inform the pilot of the minimum safe altitude. If the airplane is below the minimum safe altitude and sufficiently accurate position information has been received or radar identification is established, a heading or VOR radial on which to climb to reach the minimum safe altitude will be furnished.
CHAPTER 10 - NIGHT OPERATIONS

INTRODUCTION

This chapter introduces night operations. It includes a brief description of night visual perceptions, suggested pilot equipment, airplane lighting and equipment, airport lighting, and night-flight operations.

Night operations differ from daylight operations only by the fact that vision is restricted at night. As confidence is gained through experience, many pilots prefer night operations over day operations because the air is usually smoother, and generally, there is less air traffic to contend with.

NIGHT VISION

Generally, most pilots are poorly informed about night vision. Human eyes never function as effectively at night as the eyes of animals with nocturnal habits, but if humans learn how to use their eyes correctly and know their limitations, night vision can be improved significantly. There are several reasons for training to use the eyes correctly.

One reason is the mind and eyes act as a team for a person to see well; both team members must be used effectively. The construction of the eyes is such that to see at night they are used differently than during the day. Therefore, it is important to understand the eye’s construction and how the eye is affected by darkness.

Innumerable light-sensitive nerves, called “cones” and “rods,” are located at the back of the eye or retina, a layer upon which all images are focused. These nerves connect to the cells of the optic nerve, which transmits messages directly to the brain. The cones are located in the center of the retina, and the rods are concentrated in a ring around the cones. [Figure 10-1]
The function of the cones is to detect color, details, and faraway objects. The rods function when something is seen out of the corner of the eye or peripheral vision. They detect objects, particularly those that are moving, but do not give detail or color—only shades of gray. Both the cones and the rods are used for vision during daylight.

Although there is not a clear-cut division of function, the rods make night vision possible. The rods and cones function in daylight and in moonlight, but in the absence of normal light, the process of night vision is placed almost entirely on the rods.

The fact that the rods are distributed in a band around the cones and do not lie directly behind the pupils makes off-center viewing (looking to one side of an object) important during night flight. During daylight, an object can be seen best by looking directly at it, but at night a scanning procedure to permit off-center viewing of the object is more effective. Therefore, the pilot should consciously practice this scanning procedure to improve night vision.

The eye’s adaptation to darkness is another important aspect of night vision. When a dark room is entered, it is difficult to see anything until the eyes become adjusted to the darkness. Most everyone has experienced this after entering a darkened movie theater. In this process, the pupils of the eyes first enlarge to receive as much of the available light as possible. After approximately 5 to 10 minutes, the cones become adjusted to the dim light and the eyes become 100 times more sensitive to the light than they were before the dark room was entered. Much more time, about 30 minutes, is needed for the rods to become adjusted to darkness, but when they do adjust, they are about 100,000 times more sensitive to light than they were in the lighted area. After the adaptation process is complete, much more can be seen, especially if the eyes are used correctly.

After the eyes have adapted to the dark, the entire process is reversed when entering a lighted room. The eyes are first dazzled by the brightness, but become completely adjusted in a very few seconds, thereby losing their adaptation to the dark. Now, if the dark room is reentered, the eyes again go through the long process of adapting to the darkness.

The pilot before and during night flight must consider the adaptation process of the eyes. First, the eyes should be allowed to adapt to the low level of light and then they should be kept adapted. After the eyes have become adapted to the darkness, the pilot should avoid exposing them to any bright white light that will cause temporary blindness and could result in serious consequences.

Temporary blindness, caused by an unusually bright light, may result in illusions or after images until the eyes recover from the brightness. The brain creates these illusions reported by the eyes. This results in misjudging or incorrectly identifying objects, such as mistaking slanted clouds for the horizon or populated areas for a landing field. Vertigo is experienced as a feeling of dizziness and imbalance that can create or increase illusions. The illusions seem very real and pilots at every level of experience and skill can be affected. Recognizing that the brain and eyes can play tricks in this manner is the best protection for flying at night. Good eyesight depends upon physical condition. Fatigue, colds, vitamin deficiency, alcohol, stimulants, smoking, or medication can seriously impair vision. Keeping these facts in mind and taking adequate precautions should safeguard night vision.

In addition to the principles previously discussed, the following items will aid in increasing night vision effectiveness:

- Adapt the eyes to darkness prior to flight and keep them adapted. About 30 minutes is needed
to adjust the eyes to maximum efficiency after exposure to a bright light.

- If oxygen is available, use it during night flying. Keep in mind that a significant deterioration in night vision can occur at cabin altitudes as low as 5,000 feet.
- Close one eye when exposed to bright light to help avoid the blinding effect.
- Do not wear sunglasses after sunset.
- Move the eyes more slowly than in daylight.
- Blink the eyes if they become blurred.
- Concentrate on seeing objects.
- Force the eyes to view off center.
- Maintain good physical condition.
- Avoid smoking, drinking, and using drugs that may be harmful.

NIGHT ILLUSIONS

In addition to night vision limitations, pilots should be aware that night illusions could cause confusion and concerns during night flying. The following discussion covers some of the common situations that cause illusions associated with night flying.

On a clear night, distant stationary lights can be mistaken for stars or other aircraft. Even the northern lights can confuse a pilot and indicate a false horizon. Certain geometrical patterns of ground lights, such as a freeway, runway, approach, or even lights on a moving train can cause confusion. Dark nights tend to eliminate reference to a visual horizon. As a result, pilots need to rely less on outside references at night and more on flight and navigation instruments.

Visual autokinesis can occur when a pilot stares at a single light source for several seconds on a dark night. The result is that the light will appear to be moving. The autokinesis effect will not occur if the pilot expands the visual field. It is a good procedure not to become fixed on one source of light.

Distractions and problems can result from a flickering light in the cockpit, anti-collision light, strobe lights, or other aircraft lights and can cause flicker vertigo. If continuous, the possible physical reactions can be nausea, dizziness, grogginess, unconsciousness, headaches, or confusion. The pilot should try to eliminate any light source causing blinking or flickering problems in the cockpit.

A black-hole approach occurs when the landing is made from over water or non-lighted terrain where the runway lights are the only source of light. Without peripheral visual cues to help, pilots will have trouble orientating themselves relative to Earth. The runway can seem out of position (downsloping or upsloping) and in the worse case, results in landing short of the runway. If an electronic glide slope or visual approach slope indicator (VASI) is available, it should be used. If navigation aids (NAVAID’s) are unavailable, careful attention should be given to using the flight instruments to assist in maintaining orientation and a normal approach. If at any time the pilot is unsure of his or her position or attitude, a go-around should be executed.

Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. In this situation, the tendency is to fly a higher approach. Also, when flying over terrain with only a few lights, it will make the runway recede or appear farther away. With this situation, the tendency is common to fly a lower-than-normal approach. If the runway has a city in the distance on higher terrain, the tendency will be to fly a lower-than-normal approach. A good review of the airfield layout and boundaries before initiating
any approach will help the pilot maintain a safe approach angle.

Illusions created by runway lights result in a variety of problems. Bright lights or bold colors advance the runway, making it appear closer.

Night landings are further complicated by the difficulty of judging distance and the possibility of confusing approach and runway lights. For example, when a double row of approach lights joins the boundary lights of the runway, there can be confusion where the approach lights terminate and runway lights begin. Under certain conditions, approach lights can make the aircraft seem higher in a turn to final, than when its wings are level.

PILOT EQUIPMENT

Before beginning a night flight, carefully consider personal equipment that should be readily available during the flight. At least one reliable flashlight is recommended as standard equipment on all night flights. A D-cell size flashlight with a bulb switching mechanism that can be used to select white or red light is preferable. The white light used while performing the preflight visual inspection of the airplane, and the red light is used when performing cockpit operations. Since the red light is nonglaring, it will not impair night vision. Some pilots prefer two flashlights, one with a white light for preflight, and the other a penlight type with a red light. The latter can be suspended by a string from around the neck to ensure the light is always readily available. One word of caution; if a red light is used for reading an aeronautical chart, the red features of the chart will not show up. Remember to place a spare set of batteries in the flight kit.

Aeronautical charts are essential for night cross-country flight and, if the intended course is near the edge of the chart, the adjacent chart should also be available. The lights of cities and towns can be seen at surprising distances at night, and if this adjacent chart is not available to identify those landmarks, confusion could result. Regardless of the equipment used, organization of the cockpit eases the burden on the pilot and enhances safety.

AIRPLANE EQUIPMENT AND LIGHTING

The Air Law Regulation specifies the basic minimum airplane equipment required for night flight. This equipment includes only basic instruments, lights, electrical energy source, and spare fuses.

The standard instruments required for instrument flight are a valuable asset for aircraft control at night. An anti-collision light system, including a flashing or rotating beacon and position lights, is required airplane equipment. Airplane position lights are arranged similar to those of boats and ships. A red light is positioned on the left wingtip, a green light on the right wingtip, and a white light on the tail. [Figure 10-2]

This arrangement provides a means by which pilots can determine the general direction of movement of other airplanes in flight. If both a red and green light of another aircraft were observed, the airplane would be flying toward the pilot, and could be on a collision course.
Landing lights are not only useful for taxi, takeoffs, and landings, but also provide a means by which airplanes can be seen at night by other pilots. The Joint Aviation Administration (JAA) has initiated a voluntary pilot safety program called "operation lights on." The lights on idea is to enhance the "see and be seen" concept of averting collisions both in the air and on the ground, and to reduce the potential for bird strikes. Pilots are encouraged to turn on their landing lights when operating within 10 miles of an airport. This is for both day and night, or in conditions of reduced visibility. This should also be done in areas where flocks of birds may be expected.

Although turning on aircraft lights supports the see and be seen concept, pilots should not become complacent about keeping a sharp lookout for other aircraft. Most aircraft lights blend in with the stars or the lights of the cities at night and go unnoticed unless a conscious effort is made to distinguish them from other lights.

AIRPORT AND NAVIGATION LIGHTING AIDS

The lighting systems used for airports, runways, obstructions, and other visual aids at night are other important aspects of night flying.

Lighted airports located away from congested areas can be identified readily at night by the lights outlining the runways. Airports located near or within large cities are often difficult to identify in the maze of lights. It is important not to only know the exact location of an airport relative to the city, but also to be able to identify these airports by the characteristics of their lighting pattern.

Aeronautical lights are designed and installed in a variety of colors and configurations, each having its own purpose. Although some lights are used only during low ceiling and visibility conditions, this discussion includes only the lights that are fundamental to visual flight rules (VFR) night operation.

It is recommended that prior to a night flight, and particularly a cross-country night flight, the pilot check the availability and status of lighting systems at the destination airport. This information can be found on aeronautical charts and in the Airport/Facility Directory. The status of each facility can be determined by reviewing pertinent Notices to Airmen (NOTAM’s).

A rotating beacon is used to indicate the location of most airports. The beacon rotates at a constant speed, thus producing what appears to be a series of light flashes at regular intervals. These flashes may be one or two different colors that are used to identify various types of landing areas. For
example:

- Lighted civilian land airports—alternating white and green.
- Lighted civilian water airports—alternating white and yellow.
- Lighted military airports—alternating white and green, but are differentiated from civil airports by dual peaked (two quick) white flashes, then green.

Beacons producing red flashes indicate obstructions or areas considered hazardous to aerial navigation. Steady burning red lights are used to mark obstructions on or near airports and sometimes to supplement flashing lights on en route obstructions. High intensity flashing white lights are used to mark some supporting structures of overhead transmission lines that stretch across rivers, chasms, and gorges. These high intensity lights are also used to identify tall structures, such as chimneys and towers.

As a result of the technological advancements in aviation, runway lighting systems have become quite sophisticated to accommodate takeoffs and landings in various weather conditions. However, the pilot whose flying is limited to VFR only needs to be concerned with the following basic lighting of runways and taxiways.

The basic runway lighting system consists of two straight parallel lines of runway-edge lights defining the lateral limits of the runway. These lights are aviation white, although aviation yellow may be substituted for a distance of 2,000 feet from the far end of the runway to indicate a caution zone. At some airports, the intensity of the runway-edge lights can be adjusted to satisfy the individual needs of the pilot. The length limits of the runway are defined by straight lines of lights across the runway ends. At some airports, the runway threshold lights are aviation green, and the runway end lights are aviation red.

At many airports, the taxiways are also lighted. A taxiway-edge lighting system consists of blue lights that outline the usable limits of taxi paths.

**PREPARATION AND PREFLIGHT**

Night flying requires that pilots be aware of, and operate within, their abilities and limitations. Although careful planning of any flight is essential, night flying demands more attention to the details of preflight preparation and planning.

Preparation for a night flight should include a thorough review of the available weather reports and forecasts with particular attention given to temperature/dewpoint spread. A narrow temperature/dewpoint spread may indicate the possibility of ground fog. Emphasis should also be placed on wind direction and speed, since its effect on the airplane cannot be as easily detected at night as during the day.

On night cross-country flights, appropriate aeronautical charts should be selected, including the appropriate adjacent charts. Course lines should be drawn in black to be more distinguishable.

Prominently lighted checkpoints along the prepared course should be noted. Rotating beacons at airports, lighted obstructions, lights of cities or towns, and lights from major highway traffic all provide excellent visual checkpoints. The use of radio navigation aids and communication facilities add significantly to the safety and efficiency of night flying.
All personal equipment should be checked prior to flight to ensure proper functioning. It is very disconcerting to find, at the time of need, that a flashlight, for example, does not work. All airplane lights should be turned ON momentarily and checked for operation. Position lights can be checked for loose connections by tapping the light fixture. If the lights blink while being tapped, further investigation to determine the cause should be made prior to flight.

The parking ramp should be examined prior to entering the airplane. During the day, it is quite easy to see stepladders, chuckholes, wheel chocks, and other obstructions, but at night it is more difficult. A check of the area can prevent taxiing mishaps.

**STARTING, TAXIING, AND RUNUP**

After the pilot is seated in the cockpit and prior to starting the engine, all items and materials to be used on the flight should be arranged in such a manner that they will be readily available and convenient to use.

Extra caution should be taken at night to assure the propeller area is clear. Turning the rotating beacon ON, or flashing the airplane position lights will serve to alert persons nearby to remain clear of the propeller. To avoid excessive drain of electrical current from the battery, it is recommended that unnecessary electrical equipment be turned OFF until after the engine has been started.

After starting and before taxiing, the taxi or landing light should be turned ON. Continuous use of the landing light with RPM power settings normally used for taxiing may place an excessive drain on the airplane’s electrical system. Also, overheating of the landing light could become a problem because of inadequate airflow to carry the heat away. Landing lights should be used as necessary while taxiing. When using landing lights, consideration should be given to not blinding other pilots. Taxi slowly, particularly in congested areas. If taxi lines are painted on the ramp or taxiway, these lines should be followed to ensure a proper path along the route.

The before takeoff and run-up should be performed using the checklist. During the day, forward movement of the airplane can be detected easily. At night, the airplane could creep forward without being noticed unless the pilot is alert for this possibility. Hold or lock the brakes during the run-up and be alert for any forward movement.

**Figure 10-3.—Establish a positive climb.**
TAKE-OFF AND CLIMB

Night flying is very different from day flying and demands more attention of the pilot. The most noticeable difference is the limited availability of outside visual references. Therefore, flight instruments should be used to a greater degree in controlling the airplane. This is particularly true on night takeoffs and climbs. The cockpit lights should be adjusted to a minimum brightness that will allow the pilot to read the instruments and switches and yet not hinder the pilot’s outside vision. This will also eliminate light reflections on the windshield and windows.

After ensuring that the final approach and runway are clear of other air traffic, or when cleared for takeoff by the tower, the landing lights and taxi lights should be turned ON and the airplane lined up with the centerline of the runway. If the runway does not have centerline lighting, use the painted centerline and the runway-edge lights. After the airplane is aligned, the heading indicator should be noted or set to correspond to the known runway direction. To begin the takeoff, the brakes should be released and the throttle smoothly advanced to maximum allowable power. As the airplane accelerates, it should be kept moving straight ahead between and parallel to the runway-edge lights.

The procedure for night takeoffs is the same as for normal daytime takeoffs except that many of the runway visual cues are not available. Therefore, the flight instruments should be checked frequently during the takeoff to ensure the proper pitch attitude, heading, and airspeed is being attained. As the airspeed reaches the normal lift-off speed, the pitch attitude should be adjusted to that which will establish a normal climb. This should be accomplished by referring to both outside visual references, such as lights, and to the flight instruments.

[Figure 10-3]

After becoming airborne, the darkness of night often makes it difficult to note whether the airplane is getting closer to or farther from the surface. To ensure the airplane continues in a positive climb, be sure a climb is indicated on the attitude indicator, vertical speed indicator (VSI), and altimeter. It is also important to ensure the airspeed is at best climb speed. Necessary pitch and bank adjustments should be made by referencing the attitude and heading indicators. It is recommended that turns not be made until reaching a safe maneuvering altitude.

Although the use of the landing lights provides help during the takeoff, they become ineffective after the airplane has climbed to an altitude where the light beam no longer extends to the surface. The light can cause distortion when it is reflected by haze, smoke, or fog that might exist in the climb. Therefore, when the landing light is used for the takeoff, it may be turned off after the climb is well established provided other traffic in the area does not require its use for collision avoidance.

ORIENTATION AND NAVIGATION

Generally, at night it is difficult to see clouds and restrictions to visibility, particularly on dark nights or under overcast. The pilot flying under VFR must exercise caution to avoid flying into clouds or a layer of fog. Usually, the first indication of flying into restricted visibility conditions is the gradual disappearance of lights on the ground. If the lights begin to take on an appearance of being surrounded by a halo or glow, the pilot should use caution in attempting further flight in that same direction. Such a halo or glow around lights on the ground is indicative of ground fog. Remember that if a descent must be made through fog, smoke, or haze in order to land, the horizontal visibility is
considerably less when looking through the restriction than it is when looking straight down through it from above. Under no circumstances should a VFR night-flight be made during poor or marginal weather conditions unless both the pilot and aircraft are certificated and equipped for flight under instrument flight rules (IFR).

The pilot should practice and acquire competency in straight-and-level flight, climbs and descents, level turns, climbing and descending turns, and steep turns. Recovery from unusual attitudes should also be practiced, but only on dual flights with a flight instructor. The pilot should also practice these maneuvers with all the cockpit lights turned OFF. This blackout training is necessary if the pilot experiences an electrical or instrument light failure. Training should also include using the navigation equipment and local NAVAID’S.

In spite of fewer references or checkpoints, night cross-country flights do not present particular problems if preplanning is adequate, and the pilot continues to monitor position, time estimates, and fuel consumed. NAVAIDS, if available, should be used to assist in monitoring en route progress.

Crossing large bodies of water at night in single-engine airplanes could be potentially hazardous, not only from the standpoint of landing (ditching) in the water, but also because with little or no lighting the horizon blends with the water, in which case, depth perception and orientation become difficult. During poor visibility conditions over water, the horizon will become obscure, and may result in a loss of orientation. Even on clear nights, the stars may be reflected on the water surface, which could appear as a continuous array of lights, thus making the horizon difficult to identify.

Lighted runways, buildings, or other objects may cause illusions to the pilot when seen from different altitudes. At an altitude of 2,000 feet, a group of lights on an object may be seen individually, while at 5,000 feet or higher, the same lights could appear to be one solid light mass. These illusions may become quite acute with altitude changes and if not overcome could present problems in respect to approaches to lighted runways.

**APPROACHES AND LANDINGS**

When approaching the airport to enter the traffic pattern and land, it is important that the runway lights and other airport lighting be identified as early as possible. If the airport layout is unfamiliar to the pilot, sighting of the runway may be difficult until very close-in due to the maze of lights observed in the area. The pilot should fly toward the rotating beacon until the lights outlining the runway are distinguishable. To fly a traffic pattern of proper size and direction, the runway threshold and runway-edge lights must be positively identified. Once the airport lights are seen, these lights should be kept in sight throughout the approach. Distance may be deceptive at night due to limited lighting conditions. A lack of intervening references on the ground and the inability of the pilot to compare the size and location of different ground objects cause this. This also applies to the estimation of altitude and speed. Consequently, more dependence must be placed on flight instruments, particularly the altimeter and the airspeed indicator.

When entering the traffic pattern, allow for plenty of time to complete the before landing checklist. If the heading indicator contains a heading bug, setting it to the runway heading will be an excellent reference for the pattern legs.

Every effort should be made to maintain the recommended airspeeds and execute the approach and landing in the same manner as during the day. A low, shallow approach is definitely inappropriate
during a night operation. The altimeter and VSI should be constantly cross-checked against the airplane’s position along the base leg and final approach.

After turning onto the final approach and aligning the airplane midway between the two rows of runway-edge lights, the pilot should note and correct for any wind drift. Throughout the final approach, pitch and power should be used to maintain a stabilized approach. Flaps should be used the same as in a normal approach. Usually, halfway through the final approach, the landing light should be turned on. Earlier use of the landing light may be necessary because of “Operation Lights ON” or for local traffic considerations. The landing light is sometimes ineffective since the light beam will usually not reach the ground from higher altitudes. The light may even be reflected back into the pilot’s eyes by any existing haze, smoke, or fog. This disadvantage is overshadowed by the safety considerations provided by using the “Operation Lights On” procedure around other traffic.

The roundout and touchdown should be made in the same manner as in day landings. At night, the judgment of height, speed, and sink rate is impaired by the scarcity of observable objects in the landing area. The inexperienced pilot may have a tendency to round out too high until attaining familiarity with the proper height for the correct roundout. To aid in determining the proper roundout point, continue a constant approach descent until the landing lights reflect on the runway and tire marks on the runway can be seen clearly. At this point the roundout should be started smoothly and the throttle gradually reduced to idle as the airplane is touching down. [Figure 10-4] During landings without the use of landing lights, the roundout may be started when the runway lights at the far end of the runway first appear to be rising higher than the nose of the airplane. This demands a smooth and very timely roundout, and requires that the pilot feel for the runway surface using power and pitch changes, as necessary, for the airplane to settle slowly to the runway. Blackout landings should always be included in night pilot training as an emergency procedure.

**NIGHT EMERGENCIES**

Perhaps the pilot’s greatest concern about flying a single-engine airplane at night is the possibility of a complete engine failure and the subsequent emergency landing. This is a legitimate concern, even though continuing flight into adverse weather and poor pilot judgment account for most serious accidents.

If the engine fails at night, several important procedures and considerations to keep in mind are:

- Maintain positive control of the airplane and establish the best glide configuration and airspeed. Turn the airplane towards an airport or away from congested areas.

- Check to determine the cause of the engine malfunction, such as the position of fuel selectors, magneto switch, or primer. If possible, the cause of the malfunction should be corrected immediately and the engine restarted.

- Announce the emergency situation to Air Traffic Control (ATC) or UNICOM. If already in radio contact with a facility, do not change frequencies, unless instructed to change.

- If the condition of the nearby terrain is known, turn towards an unlighted portion of the area. Plan an emergency approach to an unlighted portion.

- Consider an emergency landing area close to public access if possible. This may facilitate
• Maintain orientation with the wind to avoid a downwind landing.

• Complete the before landing checklist, and check the landing lights for operation at altitude and turn ON in sufficient time to illuminate the terrain or obstacles along the flightpath. The landing should be completed in the normal landing attitude at the slowest possible airspeed. If the landing lights are unusable and outside visual references are not available; the airplane should be held in level-landing attitude until the ground is contacted.

• After landing, turn off all switches and evacuate the aircraft as quickly as possible.

Figure 10-4.—Roundout when tire marks are visible.
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CHAPTER 11 - NAVIGATION SYSTEMS

INTRODUCTION

This chapter reviews very high frequency (VHF) omni directional range (VOR) navigation, and discusses area navigation (RNAV), long range navigation (LORAN), and global positioning systems (GPS). For basic elements of planning and executing a cross-country and using a VOR and automatic direction finder (ADF), refer to AC 61-23, Pilot’s Handbook of Aeronautical Knowledge.

VOR NAVIGATION

For decades the VOR has been the mainstay of radio navigation. VOR, VOR/distance measuring equipment (DME), and very high frequency omni directional range/military tactical air navigation (VORTAC) symbols are shown on aeronautical charts in blue, with an adjacent frequency and Morse Code identifier. Additional Flight Service Station (FSS) communication frequencies and other symbols may also be present.

The VOR system is present in three slightly different navigation aids (NAVAID’s): VOR, VOR/DME, and VORTAC. By itself it is known as a VOR, and it provides magnetic bearing information to and from the station. When DME is also installed with a VOR, the NAVAID is referred to as a VOR/DME. When military tactical air navigation (TACAN) equipment is installed with a VOR, the NAVAID is known as a VORTAC. DME is always an integral part of a VORTAC. Regardless of the type of NAVAID utilized (VOR, VOR/DME or VORTAC), the VOR indicator behaves the same. Unless otherwise noted, in this section, VOR, VOR/DME and VORTAC NAVAID’s will all be referred to hereafter as VOR’s. The blue shaded lines drawn between VOR’s on aeronautical charts are Victor, or low altitude, airways. The magnetic bearing of each radial that comprises an airway is shown near the VOR. The letter V followed by V 4, V 71, V 159, etc. identifies the airways. Victor airways are Class E airspace and extend vertically up to but not including 18,000 feet mean sea level (MSL).

VOR’s offer simplicity of operation and are found in almost any airplane with an electrical system. Their signals are highly resistant to atmospheric disturbances. A drawback of VOR navigation is that the signal, like all VHF transmissions, is limited to line-of-sight—reception distance decreases as altitude decreases. Depending upon airplane altitude and the VOR’s service volume, ranges from 25 to 130 nautical miles (NM) can be expected. The Airport/Facility Directory classifies service volume of VOR’s as T (terminal), L (low), or H (high).

To properly utilize the VOR for navigation, the frequency of the station is first selected. The three-letter Morse code identifier may be heard by enabling the unit’s identification (IDENT) feature. This audible code should be compared with the one on the aeronautical chart for positive identification. If the OFF flag is displayed and no identifier is received, or if the letters T-E-S-T (— · • • • —) are present as an identifier, the station is unusable for navigation. Assuming that the station is operating properly, the pilot may now use the VOR indicator for navigation.

Each VOR indicator is composed of several elements: the omni bearing selector (OBS); the course index; the TO-FROM indicator; and the course deviation indicator (CDI), sometimes referred to as the Left-Right needle, or the needle. [Figure 11-1] The OBS, also known as the course selector, permits the selection of any course either to or from the VOR. The course selected is shown in the course index. The TO-FROM indicator indicates whether the selected course, if intercepted and flown, would...
take the airplane to or from the VOR. When a valid signal is not being received, the TO-FROM indicator will show OFF. Some course indicators use a separate OFF flag for this purpose. The CDI shows the relationship of the airplane to the selected course. With proper sensing, a left deflected CDI indicates that the selected course lies to the left of the airplane; a right deflected CDI indicates that the selected course lies to the right. A centered needle shows on course.

Figure 11-1.—*VOR indicator.*

The CDI displays angular deviation from the selected course. Full-scale CDI deflection is 10° on either side of the course, or 20° from full-scale left to full-scale right. The actual distance off course is dependent upon the distance from the station. Each dot of deviation equals 200 feet of linear deviation at 1 NM from the VOR, 400 feet at 2 NM, etc.

A VOR can be used to track to a station or track from a station. It can also be used for orientation in determining position in relation to a station. To track to a VOR, the pilot should tune and identify the desired station as previously described. The OBS should be turned until the CDI centers with a TO indication. The airplane should now be turned to a heading that approximates the course displayed in the course index. The needle should be kept centered with small heading corrections.

As the VOR is approached, the course will become increasingly sensitive and tracking it will require greater attention. Station passage will be indicated by the TO-FROM indicator momentarily displaying OFF, then switching to FROM. [Figure 11-2] As the TO-FROM flag momentarily displays OFF, it will be accompanied by full-scale oscillations of the needle as the airplane passes directly over the VOR.

As the VOR is crossed, the pilot may continue to fly an outbound course that is the same as the inbound course, or an entirely new outbound course may be selected. If the outbound course is the same as the inbound course, the pilot need only continue to track as before. The only difference will be a TO-FROM indicator that shows FROM.

If the pilot wishes to select a new outbound course, the OBS should be turned to select the outbound course just prior to station passage. The airplane should then be turned to a heading that will intercept the new course.

VOR’s are oriented in relation to magnetic north. Electronically, VOR’s provide an infinite number of radials. For most purposes in air navigation, however, 360 radials are assumed—one for each degree of azimuth. Proper definition and terminology here can save a lot of confusion later. Any radial, e.g., the 360° radial, the 090° radial, etc., is a line of magnetic bearing that extends from the VOR. Pilots may track either outbound or inbound on any radial. When tracking from a VOR, the outbound course
will be the same as the radial. When tracking to a VOR, the pilot is tracking inbound on a radial, and the inbound course will be the reciprocal of the radial.

Figure 11-2.—VOR tracking TO and FROM.

Figure 11-3.— Proper and reverse sensing.

To use a VOR for orientation, the pilot should select, tune, and identify the station as previously described. Using the OBS, the CDI should be centered with a FROM indication. The airplane is located on the radial displayed in the course index. Pilots should note that as the OBS is turned, the CDI will also center with a TO indication. The course shown with a TO indication is the reciprocal of the radial that the airplane is located on. For any given position of the airplane, the CDI will center on two courses. One course, if intercepted and flown, will take the airplane from the VOR. The other, if intercepted and flown, will take the airplane to the VOR. These two courses are reciprocals of one another.

The TO-FROM indicator does not tell the pilot whether the airplane is actually proceeding to or from the station at that moment. The VOR course indicator responds to and displays airplane position, not heading, in relation to the selected course. It is up to the pilot to put the airplane on an appropriate heading that will track the course.

There is an aspect called reverse sensing that must be guarded against when tracking with a VOR. [Figure 11-3] Reverse sensing occurs when the heading being flown is essentially opposite the selected course. With reverse sensing, the CDI needle deflects away from the selected course, the reverse of what is desired. Pilots can prevent reverse sensing by ensuring that the magnetic heading of the airplane is always approximately in agreement with the course being tracked. If the heading and selected course are approximately reciprocals of each other, reverse sensing occurs.

Distance measuring equipment (DME) is an ultra high frequency (UHF) navigational aid present with
VOR/DME’s and VORTAC’s. It measures, in NM, the slant range distance of an airplane from a VOR/DME or VORTAC (both hereafter referred to as a VORTAC). Although DME equipment is very popular, not all airplanes are DME equipped.

To utilize DME, the pilot should select, tune, and identify a VORTAC, as previously described. The DME receiver, utilizing what is called a “paired frequency” concept, automatically selects and tunes the UHF DME frequency associated with the VHF VORTAC frequency selected by the pilot. This process is entirely transparent to the pilot. After a brief pause, the DME display will show the slant range distance to or from the VORTAC. Slant range distance is the direct distance between the airplane and the VORTAC, and is therefore affected by airplane altitude. (Station passage directly over a VORTAC from an altitude of 6,076 feet above ground level (AGL) would show approximately 1.0 NM on the DME.) DME is a very useful adjunct to VOR navigation. A VOR radial alone merely gives line of position information. With DME, a pilot may precisely locate the airplane on that line (radial).

Most DME receivers also provide groundspeed and time-to-station modes of operation. The groundspeed is displayed in knots (NM per hour). The time-to-station mode displays the minutes remaining to VORTAC station passage, predicated upon the present groundspeed. Groundspeed and time-to-station information is only accurate when tracking directly to or from a VORTAC. DME receivers typically need a minute or two of stabilized flight directly to or from a VORTAC before displaying accurate groundspeed or time-to-station information.

Some DME installations have a hold feature that permits a DME signal to be retained from one VORTAC while the course indicator displays course deviation information from an ILS or another VORTAC.

**VOR/DME RNAV**

Area navigation (RNAV) permits electronic course guidance on any direct route between points established by the pilot. While RNAV is a generic term that applies to a variety of navigational aids, such as LORAN-C, GPS, and others, this section will deal with VOR/DME-based RNAV. VOR/DME RNAV is not a separate ground-based NAVAID, but a method of navigation using VOR/DME and VORTAC signals specially processed by the airplane’s RNAV computer. [Figure 11-4] In this section, the term “VORTAC” also includes VOR/DME NAVAID’s.

In its simplest form, VOR/DME RNAV allows the pilot to electronically move VORTAC’s around to more convenient locations. Once electronically relocated, they are referred to as waypoints. These waypoints are described as a combination of a selected radial and distance within the service volume of the VORTAC to be used. These waypoints allow a straight course to be flown between almost any
origin and destination, without regard to the orientation of VORTAC’s or the existence of airways.

While the capabilities and methods of operation of VOR/DME RNAV units differ, there are basic principals of operation that are common to all. Pilots are urged to study the manufacturer’s operating guide and receive instruction prior to the use of VOR/DME RNAV or any unfamiliar navigational system. Operational information and limitations should also be sought from placards and the supplement section of the Airplane Flight Manual (AFM) and/or Pilot’s Operating Handbook (POH).

VOR/DME-based RNAV units operate in at least three modes: VOR, En Route, and Approach. A fourth mode, VOR Parallel, may also be found on some models. The units need both VOR and DME signals to operate in any RNAV mode. If the NAVAID selected is a VOR without DME, RNAV mode will not function.

In the VOR (or non-RNAV) mode, the unit simply functions as a VOR receiver with DME capability. [Figure 11-5] The unit’s display on the VOR indicator is conventional in all respects. For operation on established airways or any other ordinary VOR navigation, the VOR mode is used.

Figure 11-5.—RNAV controls.

To utilize the unit’s RNAV capability, the pilot selects and establish a waypoint or a series of waypoints to define a course. To operate in any RNAV mode, the unit needs both radial and distance signals; therefore, a VORTAC (or VOR/DME) needs to be selected as a NAVAID. To establish a waypoint, a point somewhere within the service range of a VORTAC is defined on the basis of radial and distance. Once the waypoint is entered into the unit and the RNAV En Route mode is selected, the CDI will display course guidance to the waypoint, not the original VORTAC. DME will also display distance to the waypoint. Many units have the capability to store several waypoints, allowing them to be programmed prior to flight, if desired, and called up in flight.

RNAV waypoints are entered into the unit in magnetic bearings (radials) of degrees and tenths (i.e., 275.5°) and distances in nautical miles and tenths (i.e., 25.2 NM). When plotting RNAV waypoints on an aeronautical chart, pilots will find it difficult to measure to that level of accuracy, and in practical application, it is rarely necessary. A number of flight planning publications publish airport coordinates and waypoints with this precision and the unit will accept those figures. There is a subtle, but important difference in CDI operation and display in the RNAV modes.

In the RNAV modes, course deviation is displayed in terms of linear deviation. In the RNAV En Route mode, maximum deflection of the CDI typically represents 5 NM on either side of the selected course, without regard to distance from the waypoint. In the RNAV Approach mode, maximum deflection of the CDI typically represents 1 1/4 NM on either side of the selected course. There is no increase in CDI sensitivity as the airplane approaches a waypoint in RNAV mode.

The RNAV Approach mode is used for instrument approaches. Its narrow scale width (one-quarter of
the En Route mode) permits very precise tracking to or from the selected waypoint. In visual flight rules (VFR) cross-country navigation, tracking a course in the Approach mode is not desirable because it requires a great deal of attention and soon becomes tedious.

A fourth, lesser-used mode on some units is the VOR Parallel mode. This permits the CDI to display linear (not angular) deviation as the airplane tracks to and from VORTAC's. It derives its name from permitting the pilot to offset (or parallel) a selected course or airway at a fixed distance of the pilot's choosing, if desired. The VOR Parallel mode has the same effect as placing a waypoint directly over an existing VORTAC. Some pilots select the VOR Parallel mode when utilizing the navigation (NAV) tracking function of their autopilot for smoother a course following near the VORTAC.

Confusion is possible when navigating an airplane with VOR/DME-based RNAV, and it is essential that the pilot become familiar with the equipment installed. It is not unknown for pilots to operate inadvertently in one of the RNAV modes when the operation was not intended by overlooking switch positions or annunciators. The reverse has also occurred with a pilot neglecting to place the unit into one of the RNAV modes by overlooking switch positions or annunciators. As always, the prudent pilot is not only familiar with the equipment used, but never places complete reliance in just one method of navigation when others are available for cross-check.

**LORAN-C NAVIGATION**

Long Range Navigation, version C (LORAN-C) is another form of RNAV, but one that operates from chains of transmitters broadcasting signals in the low frequency (LF) spectrum. World Aeronautical Chart (WAC), Sectional Charts, and VFR Terminal Area Charts do not show the presence of LORAN-C transmitters. Selection of a transmitter chain is either made automatically by the unit, or manually by the pilot using guidance information provided by the manufacturer. LORAN-C is a highly accurate, supplemental form of navigation typically installed as an adjunct to VOR and ADF equipment. Databases of airports, NAVAID's and Air Traffic Control (ATC) facilities are frequently features of LORAN-C receivers.

LORAN-C is an outgrowth of the original LORAN-A developed for navigation during World War II. The LORAN-C system is used extensively in maritime applications. It experienced a dramatic growth in popularity with pilots with the advent of the small, panel-mounted LORAN-C receivers available at relatively low cost. These units are frequently very sophisticated and capable, with a wide variety of navigational functions.

With high levels of LORAN-C sophistication and capability, a certain complexity in operation is an unfortunate necessity. Pilots are urged to read the operating handbooks and to consult the supplements section of the AFM/POH prior to utilizing LORAN-C for navigation. Many units offer so many features that the manufacturers often publish two different sets of instructions: one, a brief operating guide and two, in-depth operating manual. While coverage is not global, LORAN-C signals are suitable for navigation in all of the conterminous United States, and parts of Canada and Alaska. Several foreign countries also operate their own LORAN-C systems. In the United States, the U.S. Coast Guard operates the LORAN-C system. LORAN-C system status is available from: USCG Navigation Center, Alexandria, VA (703) 313-5900.

LORAN-C absolute accuracy is excellent—typically less than .25 NM. Repeatable accuracy, or the ability to return to a waypoint previously visited, is even better. While LORAN-C is a form of RNAV, it differs significantly from VOR/DME-based RNAV. It operates in a 90 – 110 KHz frequency range and is
based upon measurement of the difference in arrival times of pulses of radio frequency (RF) energy emitted by a chain of transmitters hundreds of miles apart.

Within any given chain of transmitters, there is a master station, and from three to five secondary stations. LORAN-C units must be able to receive at least a master and two secondary stations to provide navigational information. Unlike VOR/DME-based RNAV, where the pilot must select the appropriate VOR/DME or VORTAC frequency, there is not a frequency selection in LORAN-C. The most advanced units automatically select the optimum chain for navigation. Other units rely upon the pilot to select the appropriate chain with a manual entry.

After the LORAN-C receiver has been turned on, the unit must be initialized before it can be used for navigation. While this can be accomplished in flight, it is preferable to perform this task, which can take several minutes, on the ground. The methods for initialization are as varied as the number of different models of receivers. Some require pilot input during the process, such as verification or acknowledgment of the information displayed.

Most units contain databases of navigational information. Frequently, such databases contain not only airport and NAVAID locations, but also extensive airport, airspace, and ATC information. While the unit will operate with an expired database, the information should be current or verified to be correct prior to use. The pilot can update some databases, while others require removal from the aircraft and the services of an avionics technician.

VFR navigation with LORAN-C can be as simple as telling the unit where the pilot wishes to go. The course guidance provided will be a great circle (shortest distance) route to the destination. Older units may need a destination entered in terms of latitude and longitude, but recent designs only need the identifier of the airport or NAVAID. The unit will also permit database storage and retrieval of pilot defined waypoints. LORAN-C signals follow the curvature of the Earth and are generally usable hundreds of miles from their transmitters.

The LORAN-C signal is subject to degradation from a variety of atmospheric disturbances. It is also susceptible to interference from static electricity buildup on the airframe and electrically “noisy” airframe equipment. Flight in precipitation or even dust clouds can cause occasional interference with navigational guidance from LORAN-C signals. To minimize these effects, static wicks and bonding straps should be installed and properly maintained. LORAN-C navigation information is presented to the pilot in a variety of ways. All units have self-contained displays, and some elaborate units feature built-in moving map displays. Some installations can also drive an external moving map display, a conventional VOR indicator, or a horizontal situation indicator (HSI). Course deviation information is presented as a linear deviation from course—there is no increase in tracking sensitivity as the airplane approaches the waypoint or destination. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing LORAN-C because aircraft installations can vary widely. The pilot’s familiarity with unit operation through AFM/POH supplements and operating guides cannot be overemphasized.

LORAN-C Notices To Airmen (NOTAM’s) should be reviewed prior to relying on LORAN-C for navigation. LORAN-C NOTAM’s will be issued to announce outages for specific chains and transmitters. Pilots may obtain LORAN-C NOTAM’s from FSS briefers only upon request.
The prudent pilot will never rely solely on one means of navigation when others are available for backup and cross-check. Pilots should never become so dependent upon the extensive capabilities of LORAN-C that other methods of navigation are neglected.

GLOBAL POSITIONING SYSTEM (GPS)

The global positioning system (GPS) is a satellite-based radio navigation system of increasing popularity among pilots. Its RNAV guidance is worldwide in scope. There are no symbols for GPS on aeronautical charts as it is a space-based system with global coverage. At the present time, GPS is an extremely accurate, supplemental form of navigation.

Development of the system is underway so that GPS will be capable of providing the primary means of electronic navigation. Portable and yoke mounted units are proving to be very popular in addition to those permanently installed in the airplane. Extensive navigation databases are common features in aircraft GPS receivers.

The GPS is a satellite radio navigation and time dissemination system developed and operated by the U.S. Department of Defense (DOD). Civilian interface and GPS system status is available from the U.S. Coast Guard.

It is not necessary to understand the technical aspects of GPS operation to use it in VFR/instrument flight rules (IFR) navigation. It does differ significantly from conventional, ground-based electronic navigation, and awareness of those differences is important. Awareness of equipment approvals and limitations is critical to the safety of flight. The GPS system is composed of three major elements:

1. The space segment is composed of a constellation of 26 satellites orbiting approximately 10,900 NM above the earth. The operational satellites are often referred to as the GPS constellation. The satellites are not geosynchronous but instead orbit the earth in periods of approximately 12 hours. Each satellite is equipped with highly stable atomic clocks and transmits a unique code and navigation message. Transmitting in the UHF range means that the signals are virtually unaffected by weather although they are subject to line-of-sight limitations. The satellites must be above the horizon (as seen by the receiver's antenna) to be usable for navigation.

2. The control segment consists of a master control station at Falcon AFB, Colorado Springs, CO, five monitor stations, and three ground antennas. The monitor stations and ground antennas are distributed around the Earth to allow continual monitoring and communications with the satellites. Updates and corrections to the navigational message broadcast by each satellite are up linked to the satellites as they pass over the ground antennas.

3. The user segment consists of all components associated with the GPS receiver, ranging from portable, hand-held receivers to receivers permanently installed in the aircraft. The receiver matches the satellite’s coded signal by shifting its own identical code in a matching process to precisely measure the time of arrival. Knowing the speed the signal traveled (approximately 186,000 miles per second) and the exact broadcast time, the distance traveled by the signal can be inferred from its arrival time.

To solve for its location, the GPS receiver utilizes the signals of at least four of the best positioned satellites to yield a three dimensional fix (latitude, longitude, and altitude). A two dimensional fix (latitude and longitude only) can be determined with as few as three satellites. GPS receivers have
extensive databases. Databases are provided initially by the receiver manufacturer and updated by the manufacturer or a designated data agency.

A wide variety of GPS receivers with extensive navigation capabilities are available. Panel mounted units permanently installed in the aircraft may be used for VFR and may also have certain IFR approvals. Portable hand-held and yoke mounted GPS receivers are also popular although these are limited to VFR use. Not all GPS receivers on the market are suited for air navigation. Marine, recreational, and surveying units, for example, are not suitable for aircraft use. As with LORAN-C receivers, GPS unit features and operating procedures vary widely. The pilot must be familiar with the manufacturer’s operating guide. Placards, switch positions, and annunciators should be carefully observed.

Initialization of the unit will require several minutes and should be accomplished prior to flight. If the unit has not been operated for several months or if it has been moved to a significantly different location (by several hundred miles) while off, this may require several additional minutes. During initialization, the unit will make internal integrity checks, acquire satellite signals, and display the database revision date. While the unit will operate with an expired database, the database should be current, or verified to be correct, prior to relying on it for navigation.

VFR navigation with GPS can be as simple as selecting a destination (an airport, VOR, NDB, intersection, or pilot defined waypoint) and placing the unit in the navigation mode. Course guidance provided will be a great circle route (shortest distance) direct to the destination. Many units provide advisory information about special use airspace and minimum safe altitudes, along with extensive airport data, and ATC services and frequencies. Users having prior experience with LORAN-C receivers will note many similarities in the wealth of navigation information available although the technical principles of operation are quite different.

All GPS receivers have integral (built into the unit) navigation displays and some feature integral moving map displays. Some panel mounted units will drive a VOR indicator, HSI, or even an external moving map display. GPS course deviation is linear—there is not an increase in tracking sensitivity as the airplane approaches a waypoint. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing GPS as installations and approvals can vary widely.

The integral GPS navigation display (like most LORAN-C units) uses several additional navigational terms beyond those used in NDB and VOR navigation. Some of these terms, whose abbreviations vary among manufacturers, are shown below. The pilot should consult the manufacturer’s operating guide for specific definitions.

NOTAM’s should be reviewed prior to relying on GPS for navigation. GPS NOTAM’s will be issued to announce outages for specific GPS satellites by pseudorandom noise code (PRN) and satellite vehicle number (SVN). Pilots may obtain GPS NOTAM’s from FSS briefers only upon request.

When using any sophisticated and highly capable navigation system, such as LORAN-C or GPS, there is a strong temptation to rely almost exclusively on that unit, to the detriment of using other techniques of position keeping. The prudent pilot will never rely on one means of navigation when others are available for cross-check and backup.

**RADAR SERVICES**

Radar is a device that detects objects that reflect back transmitted pulses. The reflected pulses are
electronically processed to obtain information regarding distance and azimuth. The Federal Aviation Administration (FAA) uses two types of radar systems: primary and secondary.

A primary radar system is one in which a minute portion of a radio pulse transmitted from a site is reflected by an object and then received back at the same site for processing and display at an ATC facility. With this type of system, large aircraft reflect better than small ones, and close aircraft reflect better than distant ones. Even the structure of the aircraft (wood, fabric, aluminum, or composite) affects the strength of the reflected radio pulse. A secondary radar system is one in which the aircraft responds to a radio pulse (an interrogation) from a site with a distinctive transmission from its transponder. This reply transmission, rather than the directly reflected signal, is received at the site for processing and display. Secondary radar is typically used in conjunction with primary radar at most locations although some sites are only equipped with secondary radar. Secondary radar can only display the returns of transponder equipped aircraft. This secondary radar is sometimes referred to as the air traffic control radar beacon system (ATCRBS).

There are primarily two different types of ATC radar facilities available: terminal radar approach control facilities (TRACON’s) and air route traffic control centers (ARTCC’s). Both facilities can provide radar monitoring (flight following) and radar navigational guidance (vectors).

A terminal radar approach control (TRACON) is a terminal radar facility whose primary job is separating and sequencing aircraft arriving, departing, or transitioning the area. They serve all Class B and Class C airspaces and are also found at other high activity airports. Certain major military airports have like facilities that provide similar services.

Air route traffic control centers (ARTCC’s) are widely spaced, en route radar facilities whose areas of coverage typically encompass several states. “Centers” are the controlling agency for all Class A airspace, but their radar coverage also extends to much lower altitudes. Although their primary function is separation of en route IFR traffic, radar services to VFR aircraft are provided on a workload permitting basis.

Pilots must keep several factors in mind when receiving radar services. First, ATC radar does not necessarily display all aircraft in the vicinity. Pilots must never relax vigilance for other air traffic, even when in radar contact. Secondly, ATC radar does not display clouds or other restrictions to visibility (although some primary radar systems will display significant precipitation). The pilot is always responsible for maintaining VFR visibility and cloud separation criteria. In addition, pilots are also responsible for terrain and obstruction clearance and wake turbulence avoidance. If an assigned heading or altitude compromises these responsibilities, pilots are expected to advise the controller so that an alternate clearance or instruction can be issued. Finally, radar frequencies, both primary and secondary, are limited to line-of-sight propagation paths. In fringe or marginal coverage areas, climbing to a higher altitude will assist detection.

Even when not operating in Class A (IFR only), B, or C airspace, pilots are encouraged to use radar services whenever they are available. There may be occasions when routine radar monitoring or radar vectors are not available due to frequent congestion, controller workload, equipment limitations, or other factors.
CHAPTER 12 - EMERGENCY OPERATIONS

INTRODUCTION

This chapter discusses some of the considerations for system and equipment malfunctions. It covers emergency situations, such as descents, emergency approaches, and emergency landings. It also covers general guidelines for actual emergency situations.

The Airplane Flight Manual (AFM) and/or Pilot's Operating Handbook (POH) for each airplane contains information pertinent to most emergency procedures and the safe operation of the airplane. Manufacturers also provide the checklists that complement the procedures. The owner/operator is responsible for keeping the checklists and the latest information available in the airplane for easy reference in case of an emergency. Some emergency procedures for engine failure on takeoff or inflight fire should be committed to memory and practiced so that response is timely and accurate.

SYSTEMS AND EQUIPMENT MALFUNCTIONS

Throughout each phase of flight training, several types of typical emergencies or system and equipment malfunctions will be simulated. These situations will be introduced in flight at safe altitudes to provide a better understanding of the procedures and options available.

A few emergency conditions will be discussed below. This information is general in nature, and is not intended to be used in lieu of specific procedures recommended by the manufacturer.

**Engine Fire On Start**

When an engine is primed excessively before starting, especially with cold temperatures, an induction fire may occur during start. When this occurs, the pilot should continue cranking the engine and shut off the fuel. This will normally draw the fire into the intake manifold. If the fire does not extinguish, exit the airplane. If operating from an airport with an operating control tower, advise the tower of the fire and where the airplane is located if time permits.

**Smoke/Fire In Flight**

If a pilot experiences smoke in the cabin during flight, it may be controlled by identifying and shutting down the faulty system. Heaters and all electrical equipment should be turned OFF. Smoke may be removed by opening windows or emergency exits. If the smoke intensifies, the exits and windows should be closed. After the smoke has been removed from the cabin, electrical equipment may be turned ON one item at a time until the faulty system is identified. If the source of the smoke is determined to be an upholstery fire, the fire extinguisher (if available) should be used in an attempt to put it out. Smoke entering the cabin from the engine compartment is indicative of either a heater or engine fire. In all cases the pilot should follow the manufacturer’s checklist, if one is provided.

With the use of modern installation techniques and materials, the probability of an engine fire occurring is remote. A good preflight of the airplane can reduce the possibility of engine fire by detecting conditions that could contribute to a fire. An extensive preflight inspection should be given to the engine compartment. Leaks in the fuel system, oil system, or exhaust system can lead to an inflight fire. Fire in flight must be immediately controlled. It is easily identified by an open flame or smoke coming from the engine compartment or the rapid discoloration of paint on the engine cowlign.
Fuel to the engine must be immediately cut OFF and boost pumps must be shut OFF. If the manufacturer provides a checklist for an engine fire, it must be followed. The principle concern of engine fire is major structural damage. Such an occurrence requires that a landing be made as quickly as possible. An emergency descent should be made, and if possible, Air Traffic Control (ATC) notified of the emergency. If the fire and flames are visible during the descent, attempt to slip away from the fire as much as possible. For example, if the fire is observed on the left side, consider slipping to the right. This may help move the fire away from the airplane.

**Emergency Descents**

An emergency descent is a maneuver for descending as rapidly as possible to a lower altitude or to the ground for an emergency landing. The need for this maneuver may result from an uncontrollable fire, a sudden loss of cabin pressurization, or any other situation demanding an immediate and rapid descent. The objective is to descend the airplane as soon and as rapidly as possible, within the structural limitations of the airplane. Simulated emergency descents should be made in a turn to check for other air traffic below and to look around for a possible emergency landing area. A radio call announcing descent intentions may be appropriate to alert other aircraft in the area. When initiating the descent, a bank of approximately 30 to 45° should be established to maintain positive load factors ("G" forces) on the airplane. Emergency descent training should be performed as recommended by the manufacturer, including the configuration and airspeeds. Except when prohibited by the manufacturer, the power should be reduced to idle, and the propeller control (if equipped) should be placed in the low pitch (or high revolutions per minute (RPM)) position. This will allow the propeller to act as an aerodynamic brake to help prevent an excessive airspeed buildup during the descent. The landing gear and flaps should be extended as recommended by the manufacturer. This will provide maximum drag so that the descent can be made as rapidly as possible, without excessive airspeed. The pilot should not allow the airplane’s airspeed to pass the never exceed speed (V\(_{NE}\)), the maximum gear extended speed (V\(_{LE}\)), or the maximum flap extended speed (V\(_{FE}\)), as applicable. In the case of an engine fire, a high airspeed descent could blow out the fire. However, the weakening of the airplane structure is a major concern and descent at low airspeed would place less stress on the airplane. If the descent is conducted in turbulent conditions, the pilot must also comply with the maneuvering speed (V\(_A\)) limitations. The descent should be made at the maximum allowable airspeed consistent with the procedure used. This will provide increased drag and therefore the loss of altitude as quickly as possible. The recovery from an emergency descent should be initiated at a high enough altitude to ensure a safe recovery back to level flight or a precautionary landing.

When the descent is established and stabilized during training and practice, the descent should be terminated. In airplanes with piston engines, prolonged practice of emergency descents should be avoided to prevent excessive cooling of the engine cylinders.

**Partial Power Loss**

When experiencing a partial power loss in flight, consider maintaining an airspeed that will provide the best airplane performance available. This airspeed will be approximately best glide speed.

If the power available will provide a climb at this airspeed, the pilot should climb to a more advantageous altitude. However, the pilot must consider that the engine may not continue to run very long in this condition. A decision on where to land must be made and continually updated as the flight progresses. If at this airspeed, the airplane is descending, an emergency landing will be imminent. A suitable landing area should be selected while sufficient altitude remains to allow for
necessary maneuvering. In any case, an emergency exists, and should be declared and handled accordingly. Declaring an emergency with ATC will provide for priority handling.

**Complete Power Loss**

When a complete power loss occurs in flight in a single-engine airplane, the pilot must maintain control, stabilize the airplane in best glide attitude, and follow the engine failure checklist. If power is not restored and the engine is still turning, a last resort action may be attempted by unlocking the primer and pulling it out to allow fuel to be drawn into the cylinders. If this does not restore some power, close the primer.

If a complete power loss occurs in flight in an airplane with a controllable-pitch propeller, positioning the propeller to high pitch (low RPM) can extend the glide. This option may be available provided the engine is windmilling (turning) and the propeller governor is producing oil pressure.

**Landing Gear Emergencies**

Prior to starting the engine when the master switch is turned ON, check to see if the landing gear position light(s) are illuminated. If the landing gear lights are not visible, be sure the navigation lights are turned OFF. In some airplanes the landing gear lights are dimmed for night operations and appear to be OFF during daylight.

If the landing gear fails to retract on takeoff, leave the gear in the DOWN position and return for a landing.

If during an approach to landing, the pilot extends the landing gear and it fails to extend, leave the traffic pattern and climb to a safe altitude to analyze the problem.

The first step in determining whether the landing gear is down would be to check the gear down light bulb by testing it or replacing it with another bulb. If the problem is not the bulb, recycle the landing gear. If recycling the gear is unsuccessful, close the throttle and check for the gear warning horn. In many cases the problem is only an inoperative micro switch on the landing gear. Also, slowing the airplane below maneuvering speed and yawing from side to side or applying up-elevator control sometimes will force the landing gear down into the locked position. In any procedure involving rapid control input, care must be taken not to overstress the airplane.

If a decision is made to make a gear-up landing, follow the manufacturer’s recommended procedures outlined in the checklist. In the absence of an emergency checklist, proceed as follows:

- Seat belts and shoulder harness secure.
- Normal approach.
- Throttle closed.
- Fuel OFF.
- Ignition OFF.
- Full flaps, for slowest touchdown speed.
- After landing is assured, master switch OFF.
- Land as normally and slowly as possible.

**Inadvertent Door Opening on Takeoff or In Flight**

When a cabin or baggage door opens suddenly after takeoff, the pilot must maintain control of the airplane, remain in the traffic pattern, fly a normal approach, and land as soon as possible. Although a cabin door will not open very far or cause a serious problem, the sudden noise is startling. Some loose cabin items may be drawn out of the airplane.
If an airplane baggage door opens, the pilot must maintain adequate airspeed to ensure proper control. Additional airspeed may be used on final approach and in the roundout to ensure adequate control is available until touchdown.

Always follow the instructions in the AFM/POH, if provided.

**Split Flap Condition**

An unexpected rolling motion may occur when the flaps are lowered. This rolling condition may have resulted from an asymmetrical flap condition.

In this situation follow the instructions in the AFM/POH, if provided. If information is not provided and the airplane is controllable, it may be best not to make an attempt to raise the flaps, but to land as soon as possible. An attempt to raise the flaps may possibly aggravate the situation. If the airplane is not controllable, then an attempt should be made to raise the flaps.

**EMERGENCY APPROACHES AND LANDINGS (ACTUAL)**

In spite of the remarkable reliability of present-day airplane engines, the pilot should always be prepared to cope with emergencies that may involve an emergency landing caused by partial or complete engine failure.

A study by the National Transportation Safety Board (NTSB) reveals several factors that may interfere with a pilot’s ability to act promptly and properly when faced with such an emergency:

- **Reluctance to Accept the Emergency Situation.** A pilot whose mind is allowed to become paralyzed at the thought that the airplane will be on the ground in a short time, regardless of what is done, is severely handicapped in the handling of the emergency. An unconscious desire to delay this dreaded moment may lead to errors, such as failure to lower the nose to maintain flying speed, delay in the selection of the most suitable touchdown area within reach, and indecision in general.

- **Desire to Save the Airplane.** A pilot who has been conditioned to expect to find a relatively safe landing area whenever the instructor closes the throttle for a simulated emergency landing may ignore all basic rules of airmanship to avoid a touchdown in terrain where airplane damage is unavoidable. The desire to save the airplane, regardless of the risks involved, may be influenced by the pilot’s financial stake in the airplane and the certainty that an undamaged airplane implies no bodily harm. There are times when a pilot should be more interested in sacrificing the airplane so that all occupants can safely walk away from it.

- **Undue Concern About Getting Hurt.** Fear is a vital part of our self-preservation mechanism. When fear leads to panic, we invite what we want to avoid the most. The survival records favor the pilot who maintains their composure and knows how to apply the general concepts and procedures that have been developed throughout the years.
A competent pilot is constantly on the alert for the nearest emergency landing field. Naturally, the perfect forced-landing field is an established airport, or a hard-packed, long, smooth field with out high obstacles on the approach end. These ideal conditions may not be readily available, so the best available field must be selected. Cultivated fields are usually satisfactory, and plowed fields are acceptable if the landing is made parallel to the furrows. [Figure 12-1] In any case, fields with large boulders, ditches, or other features that present a hazard during the landing should be avoided. A landing with the landing gear retracted may be advisable in soft or snow-covered fields to eliminate the possibility of the airplane nosing over, or damaging the gear, as a result of the wheels digging in.

Several factors must be considered in determining whether a field is of adequate length. When landing on a level field into a strong headwind, the distance required for a safe landing would naturally be much less than the distance required for landing with a tailwind. If it is impossible to land directly into the wind because maneuvering to an upwind approach would place the airplane at a dangerously low altitude, or a suitable field into the wind is not available, then the landing should be made crosswind or downwind. [Figure 12-2] A large field that is crosswind, or even downwind, may be safer than a smaller field that is directly into the wind. Whenever possible the pilot should select a field that is wide enough to allow extending the base leg and delaying the turn onto the final approach to correct for any error in planning. [Figure 12-3]

The direction and speed of the wind are important factors during any landing, particularly in an emergency landing, since the wind affects the airplane's gliding distance over the ground, the path over the ground during the approach, the groundspeed at which the airplane contacts the ground, and the distance the airplane rolls after the landing. All these effects should be considered during the selection of a field.

As a general rule, all landings should be made with the airplane headed into the wind, but this cannot be a hard and fast rule since many other factors may make it inadvisable in an actual emergency landing. The following are examples of such factors.

- Insufficient altitude may make it inadvisable or impossible to attempt to maneuver into the wind.
- Ground obstacles may make landing into the wind impractical or inadvisable because they shorten the effective length of the available field.
• Distance from a suitable field upwind from the present position may make it impossible to reach the field from the altitude the engine failure occurs.
• The best available field may be downhill and at such an angle to the wind that a downwind landing uphill would be preferable and safer.

Figure 12-2.— Use good judgment in choosing direction.

The altitude available is, in many ways, the controlling factor in the successful accomplishment of an emergency landing. If an actual engine failure should occur immediately after takeoff and before a safe maneuvering altitude is attained, it is usually inadvisable to attempt to turn back to the field from where the takeoff was made. Instead, it is safer to immediately establish the proper glide attitude, and select a field directly ahead or slightly to either side of the takeoff path.

Figure 12-3.— Extended base leg.

The decision to continue straight ahead is often a difficult to make unless the problems involved in attempting to turn back are seriously considered. In the first place, the takeoff was in all probability
made into the wind. To get back to the takeoff field, a downwind turn must be made. This increases the groundspeed and rushes the pilot even more in the performance of procedures and in planning the landing approach. Secondly, the airplane will be losing considerable altitude during the turn and might still be in a bank when the ground is contacted, resulting in the airplane cartwheeling (which would be a catastrophe for the occupants, as well as the airplane). After turning downwind the apparent increase in groundspeed could mislead the pilot into attempting to prematurely slow down the airplane and cause it to stall. On the other hand, continuing straight ahead or making a slight turn allows the pilot more time to establish a safe landing attitude, and the landing can be made as slowly as possible, but more importantly, the airplane can be landed while under control. Concerning the subject of turning back to the runway following an engine failure on takeoff, the pilot should determine the minimum altitude an attempt of such a maneuver would be made in a particular airplane. Experimentation at a safe altitude should give the pilot an approximation of height lost in a descending 180° turn at idle power. By adding a safety factor of about 25 percent, the pilot should arrive at a practical decision height. The ability to make a 180° turn does not necessarily mean that the departure runway can be reached in a power-off glide; this depends on the wind, the distance traveled during the climb, the height reached, and the glide distance of the airplane without power.

When an emergency landing is imminent, wind direction and speed should always be considered, but the main objective is to complete a safe landing in the best field available. This involves getting the airplane on the ground in as near a normal landing attitude as possible without striking obstructions. If the pilot gets the airplane on the ground under control, it may sustain damage, but the occupants will probably get no worse than a shaking up.

Emergency Approaches and Landings (Simulated)

From time to time on dual flights, the instructor should give simulated emergency landings by retarding the throttle and calling “simulated emergency landing.” The objective of these simulated emergency landings is to develop the pilot’s accuracy, judgment, planning, procedures, and confidence when little or no power is available.

A simulated emergency landing may be given with the airplane in any configuration. When the instructor calls “simulated emergency landing,” the pilot should immediately establish a glide attitude and ensure that the flaps and landing gear are in the proper configuration for the existing situation. When the proper glide speed is attained, the nose should then be lowered and the airplane trimmed to maintain that speed.

A constant gliding speed should be maintained because variations of gliding speed nullify all attempts at accuracy in judgment of gliding distance and the landing spot. The many variables, such as altitude, obstruction, wind direction, landing direction, landing surface and gradient, and landing distance requirements of the airplane will determine the pattern and approach procedures to use.

Utilizing any combination of normal gliding maneuvers, from wings level to spirals, the pilot should eventually arrive at the normal key position at a normal traffic pattern altitude for the selected landing area. From this point on, the approach will be as nearly as possible a normal power-off approach. [Figure 12-4]

With the greater choice of fields afforded by higher altitudes, the inexperienced pilot may be inclined to delay making a decision, and with considerable altitude in which to maneuver, errors in maneuvering and estimation of glide distance may develop.

All pilots should learn to determine the wind direction and estimate its speed from the windsock at
the airport, smoke from factories or houses, dust, brush fires, and windmills. Once a field has been selected, the student pilot should always be required to indicate it to the instructor. Normally, the student should be required to plan and fly a pattern for landing on the field first elected until the instructor terminates the simulated emergency landing. This will give the instructor an opportunity to explain and correct any errors; it will also give the student an opportunity to see the results of the errors. However, if the student realizes during the approach that a poor field has been selected—one that would obviously result in disaster if a landing were to be made—and there is a more advantageous field within gliding distance, a change to the better field should be permitted. The hazards involved in these last-minute decisions, such as excessive maneuvering at very low altitudes, should be thoroughly explained by the instructor.

![Figure 12-4.— Remain over intended landing area.](image)

Slipping the airplane, using flaps, varying the position of the base leg, and varying the turn onto final approach should be stressed as ways of correcting for misjudgment of altitude and glide angle.

Eagerness to get down is one of the most common faults of inexperienced pilots during simulated emergency landings. In giving way to this, they forget about speed and arrive at the edge of the field with too much speed to permit a safe landing. Too much speed may be just as dangerous as too little; it results in excessive floating and overshooting the desired landing spot. It should be impressed on the students that they cannot dive at a field and expect to land on it.

During all simulated emergency landings, the engine should be kept warm and cleared. During a simulated emergency landing, either the instructor or the student should have complete control of the throttle. There should be no doubt as to who has control since many near accidents have occurred from such misunderstandings.

Every simulated emergency landing approach should be terminated as soon as it can be determined whether a safe landing could have been made. In no case should it be continued to a point where it creates an undue hazard or an annoyance to persons or property on the ground.

In addition to flying the airplane from the point of simulated engine failure to where a reasonable safe landing could have been made, the student should also be taught certain emergency cockpit procedures. The habit of performing these cockpit procedures should be developed to such an extent that, when an engine failure actually occurs, the student will check the critical items that would be necessary to get the engine operating again while selecting a field and planning an approach. Combining the two operations—accomplishing emergency procedures and planning and flying the approach—will be
difficult for the student during the early training in emergency landings.

There are definite steps and procedures to be followed in a simulated emergency landing. Although they may differ somewhat from the procedures used in an actual emergency, they should be learned thoroughly by the student, and each step called out to the instructor. The use of a checklist is strongly recommended. Most airplane manufacturers provide a checklist of the appropriate items. [Figure 12-5]

Figure 12-5.— Sample emergency checklist.

**ENGINE FAILURE DURING FLIGHT**

Engine Failure
Airspeed — Glide
Fuel Selector — Fullest Tank
Fuel Pump — ON Mixture — RICH Carb Heat — ON
Magneto Switch — BOTH Flaps — UP
Gear — UP
Seat Belts — Fastened
Airspeed

**EMERGENCY LANDING**

Mixture — Idle Cutoff
Fuel Shutoff Valve — OFF Ignition Switch — OFF Flaps — As Required Master Switch — OFF

Critical items to be checked should include the position of the fuel tank selector, the quantity of fuel in the tank selected, the fuel pressure gauge to see if the electric fuel pump is needed, the position of the mixture control, the position of the magneto switch, and the use of carburetor heat. Many actual emergency landings have been made and later found to be the result of the fuel selector valve being positioned to an empty tank while the other tank had plenty of fuel. It may be wise to change the position of the fuel selector valve even though the fuel gauge indicates fuel in all tanks because fuel gauges can be inaccurate. Many actual emergency landings could have been prevented if the pilots had developed the habit of checking these critical items during flight training to the extent that it carried over into later flying.

Instruction in emergency procedures should not be limited to simulated emergency landings caused by power failures. Other emergencies associated with the operation of the airplane should be explained, demonstrated, and practiced if practicable. Among these emergencies are such occurrences as fire in flight, electrical or hydraulic system malfunctions, unexpected severe weather conditions, engine overheating, imminent fuel exhaustion, and the emergency operation of airplane systems and equipment.

**Emergency Equipment and Survival Gear**

Although the Code of Air Law Regulations do not require that specific emergency equipment and survival gear be carried on board small airplanes during flight, it is appropriate to have a few basic items in the event of an emergency situation. Items, such as a first aid kit, flashlight, container of
water, knife, matches, additional clothing, and signaling devices could be part of a basic survival kit. The contents of such a kit can be tailored to the conditions or preference of the operator.

When a pilot is planning a cross-country flight, the need for appropriate emergency equipment, clothing, and survival gear should always be included in this preparation. Some of the en route environmental conditions and factors that should be considered are:

- Type of terrain or surface to be overflown and potential for a safe emergency landing, i.e., mountains, level, remote, civilized, and water. If the route appears to be especially hazardous, a modified route should be seriously considered.
- Type of climate and temperature conditions expected, such as hot and dry or wet and cold. Supplemental clothing and water should be available if any of these conditions are expected in extreme.
- Type of emergency communications needed. This may include the use of a battery powered, hand held transceiver or a portable cellular phone.

After all these conditions and factors are considered, a better decision can be made as to what additional emergency equipment and survival gear should be included for the flight.
CHAPTER 13 - TRANSITION TO DIFFERENT AIRPLANES AND SYSTEMS

INTRODUCTION

This chapter provides guidance and a recommended structured training program for a pilot transitioning to other airplanes that have different flight characteristics, performance capabilities, operating procedures, and systems from those airplanes that the pilot has previously flown. A conscientious application of the training recommended for each airplane group will result in a more knowledgeable, competent, and safer pilot.

GENERAL

Airplane size alone is not the most important consideration on whether training is needed. Airplanes are as different as people are, and the only safe transition is to receive differences training. The following areas are considered important elements of a proper transition to a different airplane.

- Engage a qualified and authorized flight instructor or checkout pilot, as required.
- Review and understand the Airplane Flight Manual (AFM) and/or Pilot’s Operating Handbook (POH).
- Study engine and flight controls, engine and flight instruments, fuel management controls, wing flaps and landing gear controls and indicators, and avionics equipment.
- Review checklists for normal, abnormal, and emergency procedures.
- Practice slow flight; stalls; maximum performance maneuver techniques; and normal, crosswind, short-field, and soft-field takeoffs and landings, as well as normal and emergency operating procedures.
- Receive training in takeoffs, landings, and flight maneuvers with the airplane fully loaded or simulated fully loaded. This may include performance affected by higher-than-standard temperatures (density altitude). Most four place and larger airplanes handle quite differently when loaded to near maximum gross weight, as compared with operation with only two occupants in the pilot seats. Weight and balance calculations should be made for various loading conditions.
- When making a transition to any airplane, it is advisable to utilize a ground and flight training syllabus. A generic syllabus that can be adapted to most airplane checkouts is included at the end of this chapter for both ground training and flight training.

TRANSITION TO DIFFERENT MAKE AND/OR MODEL AIRPLANES

When a pilot has an opportunity to transition from one make and model airplane to another make or model, within the same class (single-engine land to single-engine land), specialized training is recommended. Although an authorized flight instructor is not required by the regulations to conduct this different make or model checkout (except in the case of high performance and complex or to a tailwheel or conventional gear airplane for the first time), it is important to remember that a well qualified instructor, or pilot with extensive experience in that particular make or model, should be utilized to provide this training.
The amount of time spent on each phase of training should be adequate to achieve satisfactory performance in each phase of ground and flight training. It is important that a comprehensive and realistic training program be conducted to ensure that a pilot can operate the new type of airplane safely.

**High Performance/Complex Airplanes**

Transition to a high performance or complex airplane can be demanding for most pilots without previous experience. These airplanes normally have increased performance and require additional planning, judgment, and skills. Therefore, it is important for a pilot to receive appropriate training before attempting to fly this type of airplane.

A high performance airplane is defined as an airplane with an engine of more than 200 horsepower. A complex airplane is defined as an airplane equipped with a retractable landing gear, wing flaps, and a controllable propeller. For a seaplane to be considered complex, it is required to have wing flaps and a controllable propeller.

Many high performance/complex airplanes have rather sophisticated systems and procedures that require additional knowledge and skills to operate safely. This may require additional ground and flight training in specific areas to ensure that proper understanding and skills have been achieved.

All complex and most high performance airplanes are equipped with a controllable propeller. This kind of propeller will require basic power management rules and procedures. Therefore, pilots must have a thorough understanding of the relationship between recommended manifold pressure and the requirements for engine or propeller revolutions per minute (RPM). Pilots must be cautioned not to exceed the recommended power.

When transitioning to a high performance or complex airplane, there are certain regulatory requirements that must be met. JAR-FCL requires that no person can act as pilot in command of a high performance or complex airplane unless that person has met certain additional requirements. These requirements include evidence that a person has received and logged ground and flight training from an authorized flight instructor in that type airplane, simulator, or flight training device that is representative of that airplane.

To meet these regulatory requirements, it is important to train with an authorized flight instructor. Upon satisfactory completion of instruction, the flight instructor certifying the pilot is proficient to operate a high performance or complex airplane will make an endorsement in the pilot’s logbook.

**AIRPLANE SYSTEMS**

When upgrading to complex airplanes, a pilot may encounter systems that are not ordinarily installed in other airplanes. A discussion on anti-icing/deicing pressurization and oxygen is included in this chapter.

**Anti-icing/Deicing Equipment**

Anti-icing/deicing equipment consists of a combination of different systems. These may be classified as either anti-icing or deicing, depending upon the function. The presence of anti-icing and deicing equipment, even though it may appear elaborate and complete, does not necessarily mean that the airplane is approved for flight in icing conditions. The AFM/POH, placards, and even the manufacturer should be consulted for specific determination of approvals and limitations.

Anti-icing equipment is provided to prevent ice from forming on certain protected surfaces. Anti-icing
equipment includes heated pitot tubes, heated or non-icing static ports and fuel vents, propeller blades with electrothermal boots or alcohol slingers, windshields with alcohol spray or electrical resistance heating, windshield defoggers, and heated stall warning lift detectors. On many turboprop engines, the lip surrounding the air intake is heated either electrically or with bleed air.

Deicing equipment is generally limited to pneumatic boots on the wing and tail leading edges. Deicing equipment is installed to remove ice that has already formed on protected surfaces. Upon pilot actuation, the boots inflate with air from the pneumatic pumps to break off accumulated ice. After a few seconds of inflation, they are deflated back to their normal position with the assistance of a vacuum. The pilot monitors the buildup of ice, and cycles the boots whenever the ice accumulation reaches a certain AFM/POH-specified thickness (one-half inch is typical).

Other equipment may include an alternate induction air source and an alternate static system source. Ice tolerant antennas may also be installed.

In the event of impact ice accumulating over normal engine air induction sources, carburetor heat (carbureted engines) or alternate air (fuel-injected engines) should be selected. A loss of engine RPM with fixed-pitch propellers and a loss of manifold pressure can detect ice buildup on normal indication sources with constant-speed propellers. On some fuel-injected engines, an alternate air source is automatically activated with blockage of the normal air source.

An alternate static system provides an alternate source of static air for the pitot-static system in the unlikely event that the primary static source becomes blocked. In nonpressurized airplanes, most alternate static sources are plumbed to the cabin. On pressurized airplanes, they are usually plumbed to a (nonpressurized) baggage compartment. The pilot activates the alternate static source by opening a valve or a fitting in the cockpit. Upon activation, the airspeed indicator, altimeter, and the vertical speed indicator (VSI) will be affected and will read somewhat in error. A correction table is frequently provided in the AFM/POH.

Anti-icing/deicing equipment only eliminates ice from the protected surfaces. Significant ice accumulation may form on unprotected areas, even with the proper use of anti-ice and deice systems. Flight at high angles of attack or even normal climb speeds will permit significant ice accumulation on lower wing surfaces that are unprotected. Many AFM/POH's mandate minimum speeds to be maintained in icing conditions. Degradation of all flight characteristics and large performance losses can be expected with ice accumulation. Pilots should not rely upon the stall warning devices for adequate stall warning when ice accumulates.

Ice will accumulate unevenly on the airplane. It will add weight and drag (primarily drag), and decrease thrust and lift. Even wing shape can affect ice accumulation; thin, airfoil sections are more prone to ice accumulation than thick, highly-cambered sections. For this reason certain surfaces, such as the horizontal stabilizer, are more prone to icing than the wing. With ice accumulations, landing approaches should be made with a minimum wing flap setting (flap extension increases the angle of attack of the horizontal stabilizer) and with an added margin of airspeed. Sudden and large configuration and airspeed changes should be avoided.

Unless otherwise recommended in the AFM/POH, the autopilot should be used only briefly in icing conditions. Continuous use of the autopilot will mask trim and handling changes that will occur with ice accumulation. Without this control feel, the pilot may not be aware of ice accumulation building to hazardous levels. The autopilot will suddenly disconnect when it reaches design limits, and the pilot may find the airplane has assumed unsatisfactory handling characteristics.
Even with deicing equipment, the prudent pilot will avoid icing conditions to the maximum extent practicable, and avoid extended flight in any icing conditions.

PRESSURIZED AIRPLANES

When an airplane is flown at a high altitude, it consumes less fuel for a given airspeed than it does for the same speed at a lower altitude. In other words, the airplane is more efficient at a high altitude. In addition, bad weather and turbulence may be avoided by flying in the relatively smooth air above the storms. Because of the advantages of flying at high altitudes, many modern general aviation-type airplanes are being designed to operate in that environment. It is important that pilots transitioning to such sophisticated equipment be familiar with at least the basic operating principles.

A cabin pressurization system accomplishes several functions in providing adequate passenger comfort and safety. It maintains a cabin pressure altitude of approximately 8,000 feet at the maximum designed cruising altitude of the airplane, and prevents rapid changes of cabin altitude that may be uncomfortable or cause injury to passengers and crew. In addition, the pressurization system permits a reasonably fast exchange of air from the inside to the outside of the cabin. This is necessary to eliminate odors and to remove stale air. Pressurization of the airplane cabin is an accepted method of protecting occupants against the effects of hypoxia. Within a pressurized cabin, occupants can be transported comfortably and safely for long periods of time, particularly if the cabin altitude is maintained at 8,000 feet or below, where the use of oxygen equipment is not required. The flight crew in this type of airplane must be aware of the danger of accidental loss of cabin pressure and must be prepared to deal with such an emergency whenever it occurs.

In the typical pressurization system, the cabin, flight compartment, and baggage compartments are incorporated into a sealed unit that is capable of containing air under a pressure higher than outside atmospheric pressure. On aircraft powered by turbine engines, bleed air from the engine compressor section is used to pressurize the cabin. Superchargers may be used on older model turbine powered airplanes to pump air into the sealed fuselage. Piston-powered airplanes may use air supplied from each engine turbocharger through a sonic venturi (flow limiter). Air is released from the fuselage by a device called an outflow valve. The outflow valve, by regulating the air exit, provides a constant inflow of air to the pressurized area.

To understand the operating principles of pressurization and air-conditioning systems, it is necessary to become familiar with some of the related terms and definitions, such as:

- Aircraft altitude—the actual height above sea level at which the airplane is flying.
- Ambient temperature—the temperature in the area immediately surrounding the airplane.
- Ambient pressure—the pressure in the area immediately surrounding the airplane.
- Cabin altitude—used to express cabin pressure in terms of equivalent altitude above sea level.
- Differential pressure—the difference in pressure between the pressure acting on one side of a wall and the pressure acting on the other side of the wall. In aircraft air-conditioning and pressurizing systems, it is the difference between cabin pressure and atmospheric pressure.

The cabin pressure control system provides cabin pressure regulation, pressure relief, vacuum relief, and the means for selecting the desired cabin altitude in the isobaric and differential range. In addition, dumping of the cabin pressure is a function of the pressure control system. A cabin pressure
regulator, an outflow valve, and a safety valve are used to accomplish these functions.

The cabin pressure regulator controls cabin pressure to a selected value in the isobaric range and limits cabin pressure to a preset differential value in the differential range. When the airplane reaches the altitude at which the difference between the pressure inside and outside the cabin is equal to the highest differential pressure for which the fuselage structure is designed, a further increase in airplane altitude will result in a corresponding increase in cabin altitude. Differential control is used to prevent the maximum differential pressure, for which the fuselage was designed, from being exceeded. This differential pressure is determined by the structural strength of the cabin and often by the relationship of the cabin size to the probable areas of rupture, such as window areas and doors.

The cabin air pressure safety valve is a combination pressure relief, vacuum relief, and dump valve. The pressure relief valve prevents cabin pressure from exceeding a predetermined differential pressure above ambient pressure. The vacuum relief prevents ambient pressure from exceeding cabin pressure by allowing external air to enter the cabin when ambient pressure exceeds cabin pressure. The cockpit control switch actuates the dump valve. When this switch is positioned to ram, a solenoid valve opens, causing the valve to dump cabin air to atmosphere.

The degree of pressurization and the operating altitude of the aircraft are limited by several critical design factors. Primarily the fuselage is designed to withstand a particular maximum cabin differential pressure.

Several instruments are used in conjunction with the pressurization controller. The cabin differential pressure gauge indicates the difference between inside and outside pressure. This gauge should be monitored to assure that the cabin does not exceed the maximum allowable differential pressure. A cabin altimeter is also provided as a check on the performance of the system. In some cases, these two instruments are combined into one. A third instrument indicates the cabin rate of climb or descent. A cabin rate-of-climb instrument and a cabin altimeter are illustrated in Figure 13-1.

![Figure 13-1.—Cabin pressurization instruments.](image)

Decompression is defined as the inability of the airplane’s pressurization system to maintain its designed pressure differential. This can be caused by a malfunction in the pressurization system or structural damage to the airplane. Physiologically, decompressions fall into two categories, they are:

- **Explosive Decompression**—Explosive decompression is defined as a change in cabin pressure faster than the lungs can decompress; therefore, it is possible that lung damage may occur. Normally, the time required to release air from the lungs without restrictions, such as masks, is 0.2 seconds. Most authorities consider any decompression that occurs in less than 0.5 seconds as explosive and potentially dangerous.

- **Rapid Decompression**—Rapid decompression is defined as a change in cabin pressure where
the lungs can decompress faster than the cabin; therefore, there is no likelihood of lung damage.

During an explosive decompression, there may be noise, and for a split second, one may feel dazed. The cabin air will fill with fog, dust, or flying debris. Fog occurs due to the rapid drop in temperature and the change of relative humidity. Normally, the ears clear automatically. Air will rush from the mouth and nose due to the escape of air from the lungs, and may be noticed by some individuals.

The primary danger of decompression is hypoxia. Unless proper utilization of oxygen equipment is accomplished quickly, unconsciousness may occur in a very short time. The period of useful consciousness is considerably shortened when a person is subjected to a rapid decompression. This is due to the rapid reduction of pressure on the body—oxygen in the lungs is exhaled rapidly. This in effect reduces the partial pressure of oxygen in the blood and therefore reduces the pilot’s effective performance time by one-third to one-fourth its normal time. For this reason, the oxygen mask should be worn when flying at very high altitudes (35,000 feet or higher). It is recommended that the crewmembers select the 100 percent oxygen setting on the oxygen regulator at high altitude if the airplane is equipped with a demand or pressure demand oxygen system.

Another hazard is being tossed or blown out of the airplane if near an opening. For this reason, individuals near openings should wear safety harnesses or seatbelts at all times when the airplane is pressurized and they are seated.

Another potential hazard during high altitude decompressions is the possibility of evolved gas decompression sicknesses. Exposure to wind blasts and extremely cold temperatures are other hazards one might have to face.

Rapid descent from altitude is necessary if these problems are to be minimized. Automatic visual and aural warning systems are included in the equipment of all pressurized airplanes.

OXYGEN SYSTEMS

Most high altitude airplanes come equipped with some type of fixed oxygen installation. If the airplane does not have a fixed installation, portable oxygen equipment must be readily accessible during flight. The portable equipment usually consists of a container, regulator, mask outlet, and pressure gauge. Aircraft oxygen is usually stored in high pressure system containers of 1,800 – 2,200 pounds per square inch (PSI). When the ambient temperature surrounding an oxygen cylinder decreases, pressure within that cylinder will decrease because pressure varies directly with temperature if the volume of a gas remains constant. If a drop in indicated pressure on a supplemental oxygen cylinder is noted, there is no reason to suspect depletion of the oxygen supply, which has simply been compacted due to storage of the containers in an unheated area of the aircraft. High pressure oxygen containers should be marked with the PSI tolerance (i.e., 1,800 PSI) before filling the container to that pressure. The containers should be supplied with aviation oxygen only, which is 100 percent pure oxygen. Industrial oxygen is not intended for breathing and may contain impurities, and medical oxygen contains water vapor that can freeze in the regulator when exposed to cold temperatures. To assure safety, oxygen system periodic inspection and servicing should be done.

An oxygen system consists of a mask and a regulator that supplies a flow of oxygen dependent upon cabin altitude. Regulators approved for use up to 40,000 feet are designed to provide zero percent cylinder oxygen and 100 percent cabin air at cabin altitudes of 8,000 feet or less, with the ratio
changing to 100 percent oxygen and zero percent cabin air at approximately 34,000 feet cabin altitude. Regulators approved up to 45,000 feet are designed to provide 40 percent cylinder oxygen and 60 percent cabin air at lower altitudes, with the ratio changing to 100 percent at the higher altitude. Pilots should avoid flying above 10,000 feet without oxygen during the day and above 8,000 feet at night.

Pilots should be aware of the danger of fire when using oxygen. Materials that are nearly fireproof in ordinary air may be susceptible to burning in oxygen. Oils and greases may catch fire if exposed to oxygen, and cannot be used for sealing the valves and fittings of oxygen equipment. Smoking during any kind of oxygen equipment use is prohibited. Before each flight, the pilot should thoroughly inspect and test all oxygen equipment. The inspection should include a thorough examination of the aircraft oxygen equipment, including available supply, an operational check of the system, and assurance that the supplemental oxygen is readily accessible. The inspection should be accomplished with clean hands and should include a visual inspection of the mask and tubing for tears, cracks, or deterioration; the regulator for valve and lever condition and positions; oxygen quantity; and the location and functioning of oxygen pressure gauges, flow indicators and connections. The mask should be donned and the system should be tested. After any oxygen use, verify that all components and valves are shut off.

**Masks**

There are numerous types of oxygen masks in use that vary in design detail. It would be impractical to discuss all of the types in this handbook. It is important that the masks used be compatible with the particular oxygen system involved. Crew masks are fitted to the user’s face with a minimum of leakage. Crew masks usually contain a microphone. Most masks are the oronasal-type, which covers only the mouth and nose.

Passenger masks may be simple, cup-shaped rubber moldings sufficiently flexible to obviate individual fitting. They may have a simple elastic head strap or the passenger may hold them to the face.

All oxygen masks should be kept clean. This reduces the danger of infection and prolongs the life of the mask. To clean the mask, wash it with a mild soap and water solution and rinse it with clear water. If a microphone is installed, use a clean swab, instead of running water, to wipe off the soapy solution. The mask should also be disinfected. A gauze pad that has been soaked in a water solution of Merthiolate can be used to swab out the mask. This solution should contain one-fifth teaspoon of Merthiolate per quart of water. Wipe the mask with a clean cloth and air dry.

**Diluter Demand Oxygen Systems**

Diluter demand oxygen systems supply oxygen only when the user inhales through the mask. An automix lever allows the regulators to automatically mix cabin air and oxygen or supply 100 percent oxygen, depending on the altitude. The demand mask provides a tight seal over the face to prevent dilution with outside air and can be used safely up to 40,000 feet. A pilot who has a beard or mustache should be sure it is trimmed in a manner that will not interfere with the sealing of the oxygen mask. The fit of the mask around the beard or mustache should be checked on the ground for proper sealing.

**Pressure Demand Oxygen Systems**

Pressure demand oxygen systems are similar to diluter demand oxygen equipment, except that oxygen is supplied to the mask under pressure at cabin altitudes above 34,000 feet. Pressure demand regulators also create airtight and oxygen-tight seals, but they also provide a positive pressure
application of oxygen to the mask face piece that allows the user’s lungs to be pressurized with oxygen. This feature makes pressure demand regulators safe at altitudes above 40,000 feet. Some systems may have a pressure demand mask with the regulator attached directly to the mask, rather than mounted on the instrument panel or other area within the flight deck. The mask-mounted regulator eliminates the problem of a long hose that must be purged of air before 100 percent oxygen begins flowing into the mask.

**Continuous Flow Oxygen System**

Continuous flow oxygen systems are usually provided for passengers. The passenger mask typically has a reservoir bag, which collects oxygen from the continuous flow oxygen system during the time when the mask user is exhaling. The oxygen collected in the reservoir bag allows a higher inspiratory flow rate during the inhalation cycle, which reduces the amount of air dilution. Ambient air is added to the supplied oxygen during inhalation after the reservoir bag oxygen supply is depleted. The exhaled air is released to the cabin.

**Servicing of Oxygen Systems**

Certain precautions should be observed whenever aircraft oxygen systems are to be serviced. Before servicing any aircraft with oxygen, consult the specific aircraft service manual to determine the type of equipment required and procedures to be used. Oxygen system servicing should be accomplished only when the aircraft is located outside of the hangars. Personal cleanliness and good housekeeping are imperative when working with oxygen. Oxygen under pressure and petroleum products creates spontaneous results when they are brought in contact with each other. Service people should be certain to wash dirt, oil, and grease (including lip salves and hair oil) from their hands before working around oxygen equipment. It is also essential that clothing and tools are free of oil, grease, and dirt. Aircraft with permanently installed oxygen tanks usually require two persons to accomplish servicing of the system. One should be stationed at the service equipment control valves, and the other stationed where he or she can observe the aircraft system pressure gauges. Oxygen system servicing is not recommended during aircraft fueling operations or while other work is performed that could provide a source of ignition. Oxygen system servicing while passengers are on board the aircraft is not recommended.

**PHYSIOLOGICAL ALTITUDE LIMITS**

The response of human beings to increased altitude varies with each individual. People who are in poor health will be affected at a much lower altitude than people who are in good physical condition. Without supplementary oxygen, most people will begin to experience a reduction in night vision or general visual acuity at approximately 5,000 feet. At an altitude of approximately 10,000 feet, a person will begin to display measurable deterioration in mental abilities and physical dexterity after a period of several hours. At 18,000 feet, the mental deterioration may result in unconsciousness, and the time of useful consciousness (TUC) is generally about 15 minutes. At 25,000 feet, the TUC for most people is about 3 - 10 minutes. At altitudes above 25,000 feet, the TUC decreases very rapidly, becoming only a few seconds at 40,000 feet. If a person is breathing 100 percent oxygen, the partial pressure of oxygen in the lungs at 34,000 feet is the same as that for a person breathing air at sea level. At 40,000 feet, a person breathing 100 percent oxygen will have the same partial pressure of oxygen in the lungs as a person breathing air at 10,000 feet. Therefore, 34,000 feet is the highest altitude a person would be provided complete protection from the effects of hypoxia, and 40,000 feet is the highest altitude 100 percent oxygen will provide reasonable protection for the limited period of time needed to descend to a safe altitude.
REGULATORY REQUIREMENTS

JAR-FCL requires that the minimum flightcrew on civil aircraft be provided with and use supplemental oxygen at cabin pressure altitudes above 12,500 feet mean sea level (MSL) up to and including 14,000 feet MSL for the portion of the flight that is at these altitudes for more than 30 minutes. The required minimum flightcrew must be provided with and use supplemental oxygen at all times when operating an aircraft above 14,000 feet MSL. At cabin pressure altitudes above 15,000 feet MSL, all occupants of the aircraft must be provided with supplemental oxygen.

Air Rule also requires pressurized aircraft to have at least a 10-minute additional supply of supplemental oxygen for each occupant at flight altitudes above FL 250 in the event of decompression. At flight altitudes above FL 350, one pilot at the controls of the airplane must wear and use an oxygen mask that is secured and sealed. The oxygen mask must supply oxygen at all times or must automatically supply oxygen when the cabin pressure altitude of the airplane exceeds 14,000 feet MSL. An exception to this regulation exists for two-pilot crews that operate at or below FL 410. One pilot does not need to wear and use an oxygen mask if both pilots are at the controls and each pilot has a quick donning type of oxygen mask that can be placed on the face with one hand from the ready position and be properly secured, sealed, and operational within 5 seconds. If one pilot of a two-pilot crew is away from the controls, then the pilot that is at the controls is required to wear and use an oxygen mask that is secured and sealed.
CHAPTER 14 - TRANSITION TO A MULTIENGINE AIRPLANE

INTRODUCTION

This chapter discusses the factors involved in the operation of multiengine airplanes. This involves normal and emergency procedures during ground and flight operations.

MULTIENGINE PERFORMANCE CHARACTERISTICS

The term “multiengine” as used here pertains to the propeller driven airplane having a maximum certificated gross weight of less than 12,500 pounds, and which has two reciprocating airplane engines mounted on the wings.

From the transitioning pilot’s point of view, the basic difference between a multiengine and single-engine airplane is the potential problem involving engine failure. The information that follows is confined to that one basic difference.

Before the subject of operating procedures in multiengine airplanes can be thoroughly discussed, there are several terms that need to be reviewed. V-speeds, such as VXSE, VYSE, VSSE, and VMC are the new speeds the multiengine pilot needs to know in addition to the other V-speeds that are common to both multiengine and single-engine airplanes. The airspeed indicator in multiengine airplanes is marked (in addition to other normally marked speeds) with a red radial line at the minimum controllable airspeed (VMC) with the critical engine inoperative and a blue radial line at the best rate-of-climb airspeed (VYSE) with one engine inoperative. [Figure 14-1]

- VR—Rotation speed. The speed at which rotation is initiated during takeoff.
- VLOF—Lift-off speed.
- VX—Best angle-of-climb speed. At this speed, the airplane will gain the greatest height for a given distance of forward travel. This speed is used for obstacle clearance with all engines operating.
- VXSE—Best angle-of-climb speed (single-engine). At this speed, the airplane will gain the greatest height for a given distance of forward travel. This speed is used for obstacle clearance with one engine inoperative.
- VY—Best rate-of-climb speed. This speed will provide the maximum altitude gain for a given period of time with all engines operating.
- VYSE—Best rate-of-climb speed (single-engine). This speed will provide the maximum altitude gain for a given period of time with one engine inoperative.
- VSSE—Intentional one-engine-inoperative speed. The speed above both VMC and stall speed selected by the manufacturer to provide a margin of lateral and directional control when one engine is suddenly rendered inoperative. Intentional failing of one engine below this speed is
not recommended.

- **$V_M C$**—Minimum control speed. The minimum flight speed at which the airplane is controllable with a bank of not more than $5^\circ$ into the operating engine when one engine suddenly becomes inoperative and the remaining engine is operating at takeoff power.

- **$V_{MCA}$**—Minimum control speed with one engine inoperative (in flight). The minimum airspeed in flight at which directional control can be maintained, when one engine is suddenly made inoperative. $V_{MCA}$ is a function of engine thrust that varies with altitude and temperature.

- **$V_{MCG}$**—Minimum control speed with one engine inoperative (on the ground). The minimum airspeed on the ground at which directional control can be maintained, when one engine is suddenly made inoperative, using only aerodynamic controls. $V_{MCG}$ is a function of engine thrust that varies with altitude and temperature.

Figure 14-1.—Airspeed indicator markings for a multiengine airplane.

Figure 14-2.—Forces created during single-engine operation.
THE CRITICAL ENGINE

P-factor is present in multiengine airplanes just as it is in single-engine airplanes. Remember that P-factor is caused by the dissimilar thrust of the rotating propeller blades when in certain flight conditions. It is the result of the downward moving blade having a greater angle of attack than the upward moving blade when the relative wind striking the blades is not aligned with the thrust line (as in a nose-high attitude).

In most U.S. designed multiengine airplanes, both engines rotate to the right (clockwise) when viewed from the rear, and both engines develop an equal amount of thrust. At low airspeed and high-power conditions, the downward moving propeller blade of each engine develops more thrust than the upward moving blade. This asymmetric propeller thrust or P-factor, results in a center of thrust at the right side of each engine as indicated by lines D1 and D2 in Figure 14-2. The turning (or yawing) force of the right engine is greater than the left engine since the center of thrust (D2) is much farther away from the centerline (CL) of the fuselage because it has a longer leverage arm. When the right engine is operative and the left engine is inoperative, the turning (or yawing) force is greater than in the opposite situation of an operative left engine and an inoperative right engine. In other words, directional control is more difficult when the left engine (the critical engine) is suddenly made inoperative.

Some multiengine airplanes are equipped with engines turning in opposite directions; that is, the left engine and propeller turn clockwise and the right engine and propeller turn counterclockwise. With this arrangement, the thrust line of either engine is the same distance from the centerline of the fuselage, so there will be no difference in yaw effect between loss of left or right engine. In this case, there is not an engine designated as critical.

VMC FOR CERTIFICATION

$V_{MC}$ for airplane certification is based on the critical engine becoming inoperative and windmilling, up to 5° of bank towards the operative engine, takeoff power on operative engine, landing gear up, flaps in takeoff position, maximum gross weight, and most rearward center of gravity (CG).

Under some conditions of weight and altitude, a stall can be encountered at speeds above $V_{MC}$ as established by the certification procedure described above, in which event the stall speed is regarded as the limit of effective directional control.

The regulations under which the airplane was certificated stipulate that at $V_{MC}$ the certificating test pilot must be able to:

- Stop the turn that results when the critical engine is suddenly made inoperative within 20° of the original heading, using maximum rudder deflection, and not more than 5° of bank into the operative engine.

- After recovery, maintain the airplane in straight flight with not more than a 5° of bank towards the operating engine. This does not mean that the airplane is required to be able to climb or even hold altitude. It only means that the heading can be maintained.

$V_{MC}$—Minimum Control Airspeed

The principle of $V_{MC}$ is that at any airspeed less than $V_{MC}$, with up to 5° of bank towards the
operative engine (bank depends on manufacturer), air flowing along the rudder is such that the application of rudder forces cannot overcome the asymmetrical yawing forces caused by takeoff power on one engine and a powerless windmilling propeller on the other. The demonstration of VMC is discussed in a later section of this chapter.

When one engine fails, the pilot must overcome the asymmetrical thrust (except on airplanes with centerline thrust) created by the operating engine by setting up a counteracting moment with the rudder. When the rudder is fully deflected, its yawing power will depend on the velocity of airflow across the rudder, which in turn is dependent on the airspeed. As the airplane decelerates, it will reach a speed below which the rudder moment will no longer balance the thrust moment and directional control will be lost.

During single-engine flight, the large rudder deflection required to counteract the asymmetric thrust also results in a lateral lift force on the vertical fin. This lateral lift represents an unbalanced side force on the airplane that must be counteracted by allowing the airplane to accelerate sideways until the lateral drag caused by the sideslip equals the rudder lift force.

In this case, the wings will be level, the ball in the turn-and-slip indicator will be centered, and the airplane will be in a moderate sideslip toward the inoperative engine. Flight tests have shown that holding the ball of the turn-and-slip indicator in the center while maintaining heading with wings level drastically increases $V_{MC}$ as much as 20 knots in some airplanes. Banking toward the operative engine reduces $V_{MC}$, whereas decreasing the bank angle away from the operative engine increases $V_{MC}$ at the rate of approximately 3 knots per degree of bank angle.

Flight tests have also shown that the high drag caused by the wings level, ball centered configuration can reduce single-engine climb performance by as much as 300 feet per minute (FPM), which is just about all that is available at sea level in a nonturbocharged multiengine airplane.

The sideslipping method has several major disadvantages.

- The relative wind blowing on the inoperative engine side of the vertical fin tends to increase the asymmetric moment caused by the failure of one engine.
- The resulting sideslip severely degrades stall characteristics.
- The greater rudder deflection required to balance the extra moment and the sideslip drag cause a significant reduction in climb and/or acceleration capability.

Banking into the operating engine and using a component of the airplane weight to counteract the rudder induced side force lowers $V_{MC}$, by increasing the slip angle. The resulting stable yawing moment reduces the rudder deflection required. In a one-engine inoperative condition in stabilized flight with a 5° bank into the operating engine, the pilot cannot choose the sideslip angle without using a calibrated sideslip vane or yaw string. At zero sideslip, the ball will have a large deflection toward the operating engine. In unaccelerated flight, the ball is really a bank indicator and does not give information about sideslip angle. A pilot cannot intentionally fly the airplane at the minimum drag condition of zero sideslip (or minimum sideslip) without an indicator, such as a yaw string. The ball position can be determined for any airplane by using a yaw string during single-engine training and the ball position noted for zero slip.
The correct procedure for flying at zero slip is wings banked into the operating engine, the ball deflected toward the operative engine as determined by a yaw string. The amount of bank varies with the type of airplane, weight, and density altitude. This will maximize single-engine performance for best climb performance, and stall characteristics will not be degraded. When zero slip bank angle is exceeded, performance is degraded. The magnitude of these effects will vary from airplane to airplane, but the principles are applicable in all cases. A bank limitation of up to 5° during VMC demonstration is applicable only to certification tests of the airplane, and is not intended as a limit in training or testing a pilot’s ability to extract maximum performance from the airplane. Single-engine flight with the ball centered is never a correct configuration and, in fact, will degrade performance and result in unsafe stall characteristics.

For an airplane with nonturbocharged engines, VMC decreases as altitude is increased. Consequently, directional control can be maintained at a lower airspeed than at sea level. The reason for this is that since power decreases with altitude the thrust moment of the operating engine becomes less, thereby lessening the need for the rudder’s yawing force. Since VMC is a function of power (which decreases with altitude), it is possible for the airplane to reach a stall speed prior to the loss of directional control.

It must be understood that there is a certain density altitude above which the stalling speed is higher than the single-engine minimum control speed. This maneuver can still be effectively performed by limiting rudder travel or by limiting the power setting to less than takeoff power. Before flight demonstrations, the significance of the single-engine minimum control speed, including the results of attempting flight below this speed with one engine inoperative, the recognition of the imminent loss of control, and the recovery procedures involved should be orally emphasized.

VMC is greater when the CG is at the rearmost allowable position. Since the airplane rotates around its CG, the moments are measured using that point as a reference. A rearward CG would not affect the thrust moment, but would shorten the arm to the center of the rudder's horizontal lift, which would mean that a higher force (airspeed) would be required to counteract the engine inoperative yaw. Figure 14-3 shows an exaggerated view of the effects of a rearward CG.

Generally, the CG range of most multiengine airplanes is short enough so that the effect on the VMC is relatively small, but it is a factor that should be considered. Many pilots only consider the rear CG of their multiengine airplanes as a factor for pitch stability, not realizing that it could affect the controllability with one engine inoperative.

While in straight-and-level flight, the airplane weight will not affect VMC; however, banking into the operating engine creates a horizontal component of lift. This component pulls the airplane into the operating engine, counteracting adverse yaw, requiring less rudder deflection. The heavier the
airplane, the stronger the horizontal component of lift, and the lower \( V_{MC} \) becomes.

There are many multiengine pilots who think that the only control problem experienced in flight below \( V_{MC} \) is a yaw toward the inoperative engine. With full power applied to the operative engine, as the airspeed drops below \( V_{MC} \), the airplane tends to roll, as well as yaw into the inoperative engine. This tendency becomes greater as the airspeed is further reduced. Since this tendency must be counteracted by aileron control, the yaw condition is aggravated by aileron yaw (the down aileron creates more drag than the up aileron). If a stall should occur in this condition, a violent roll into the inoperative (dead) engine may be experienced. Such an event occurring close to the ground could be disastrous. This may be avoided by maintaining airspeed above \( V_{SSE} \) at all times during single-engine operations. If the airspeed should fall below \( V_{SSE} \) and approach \( V_{MC} \), then power must be reduced on the operative engine and the airplane must be banked at least 5\(^\circ\) toward the operative engine.

**PERFORMANCE**

Many pilots erroneously believe that because an airplane has two engines, it will continue to perform at least half as well with only one engine operating. There is nothing in air law, governing the certification of multiengine airplanes which requires an airplane to maintain altitude while in the takeoff configuration and with one engine inoperative. In fact, many of the current multiengine airplanes are not required to do this with one engine inoperative in any configuration, even at sea level. With regard to performance (but not controllability) in the takeoff or landing configuration, the multiengine airplane is, in concept, merely a single-engine airplane with its power divided into two individual units.

When one engine fails on a multiengine airplane, performance is not halved, but is reduced by approximately 80 percent. The performance loss is greater than 50 percent because an airplane’s climb performance is a function of the thrust horsepower which is in excess of that required for level flight. When power is increased in both engines in level flight and the airspeed is held constant, the airplane will start climbing. The rate of climb depends on the power added (which is power in excess of that required for straight-and-level flight). When one engine fails, however, it not only loses power, but the drag increases considerably because of asymmetric thrust, and the operating engine then carries the full burden alone. This leaves very little excess power for climb performance.

For example, an airplane that has an all-engine rate of climb of 1,860 FPM and a single-engine rate of climb of 190 FPM would lose almost 90 percent of its climb performance when one engine fails.

**FACTORS IN TAKEOFF PLANNING**

Pilots of multiengine airplanes will plan the takeoff in sufficient detail to be able to take immediate action if one engine fails during the takeoff process. They will be thoroughly familiar with the airplane’s performance capabilities and limitations, including accelerate/stop distance, as well as the distance available for takeoff, and will include such factors in their plan of action. If it has been determined that the airplane cannot maintain altitude with one engine inoperative (considering the gross weight and density altitude), an immediate landing may have to be made in the most suitable area available when an engine fails on lift-off. The competent pilot will not make an attempt to maintain altitude at the expense of a safe airspeed.

Also consider the surrounding terrain, obstructions, and nearby landing areas so that a definite direction of flight can be established immediately if an engine fails at a critical point during the climb.
after takeoff. It is imperative that the takeoff and climb path be planned so that all obstacles between
the point of takeoff and the available areas of landing can be cleared if one engine suddenly becomes
inoperative.

In addition, a competent pilot knows that the multiengine airplane has to be flown with precision if
maximum takeoff performance and safety are to be obtained. For example, the airplane must lift off
at a specific airspeed, accelerate to a definite climbing airspeed, and climb with maximum allowable
power on both engines to a safe single-engine maneuvering altitude. In the meantime, if an engine
fails, a different airspeed must be attained immediately. This airspeed must be held precisely because
only at this airspeed will the pilot be able to obtain maximum performance from the airplane. To
understand the factors involved in proper takeoff planning, a further explanation of this critical speed
follows, beginning with the lift-off.

The airplane can be controlled satisfactorily while firmly on the ground when one engine fails prior to
reaching VMC during the takeoff roll. This is possible by closing both throttles, by proper use of
rudder and brakes, and with many airplanes, by use of nosewheel steering. If the airplane is airborne
at less than VMC, however, and suddenly loses all power on one engine, it cannot be controlled
satisfactorily. On normal takeoffs, follow the manufacturer’s recommended rotation speed (VR) or lift-
off speed (VLOF). If speeds are not published, use a minimum speed of VMC plus 5 knots before lift-
off. Lift-off should never take place until the airspeed reaches and exceeds VMC. From this point, an
efficient climb procedure should be followed. [Figure 14-4]

Figure 14-4.—Normal takeoff procedure.

An efficient climb procedure is one in which the airplane leaves the ground above VMC, accelerates
quickly to VY (best rate-of-climb speed) and climbs at VY. The climb at VY should be made with both
engines set to maximum takeoff power until reaching a safe single-engine maneuvering altitude
(minimum of approximately 500 feet above field elevation or as dictated by airplane performance
capability and/or local obstacles). At this point, power may be reduced to climb power, and the
desired en route climb speed may then be established. The following discussion explains why VY is
recommended for the initial climb.

When an engine fails on takeoff below VY speed with no bank angle correction, VMC could be 15 to
20 knots above published. This will occur because published VMC is based up to a maximum of 5° of
bank into the operating engine. Tests have shown that VMC increases approximately 3 knots for each
degree of bank less than 5. With no bank when the engine initially fails, the higher speed of VY will
allow the pilot time to increase the bank angle up to 8° or higher, if necessary, to maintain control of
the airplane and establish VYSE. By increasing the bank angle above 5°, the pilot lowers VMC even
more than published $V_{MC}$, but is sacrificing climb performance. During an initial engine failure, this will help maintain control. Once control and airspeed are established, bank angle can be reduced to as little as 2 to 3° of bank to increase climb performance.

Extremes in takeoff technique may suggest hold it down to accelerate the airplane to near cruise speed before climbing, or pull it off below $V_{MC}$ and climb as steeply as possible. If one considers the possibility of an engine failure somewhere during the takeoff, neither of these procedures makes much sense for the following reasons. Remember that drag increases as the square of the speed, so for any increase in speed over and above the best rate-of-climb speed ($V_Y$) the greater the drag and the less climb performance the airplane will have. At 123 knots the drag is approximately one and one-half times greater than it is at 100 knots. At 141 knots the drag is doubled, and at 200 knots the drag is approximately four times as great as at 100 knots. While the drag is increasing as the square of the velocity ($V \times V$), the power required to maintain a velocity increases as the cube of that velocity ($V \times V \times V$).

In the event of engine failure, a pilot who uses excessive speed on takeoff will suddenly discover that all energy produced by the engines has been converted into speed. Some pilots believe that the excess speed can always be converted to altitude, but this theory is invalid. Available power is only wasted in accelerating the airplane to an unnecessary speed. Also, experience has shown that an unexpected engine failure so surprises the inexperienced pilot that proper reactions are extremely lagging. By the time the initial shock wears off and the pilot is ready to take control of the situation, the excess speed has dissipated and the airplane is still barely off the ground. From this low altitude, the pilot would still have to climb, with an engine inoperative, to whatever height is needed to clear all obstacles and return to the approach end of the runway. Excess speed cannot be converted readily to the altitude or distance necessary to reach a landing area safely.

In contrast, an airplane will fly in level flight much easier than it will climb. Therefore, if the total energy of both engines is initially converted to enough height above the ground to permit clearance of all obstacles while in level flight (safe maneuvering altitude), the problem is much simpler in the event an engine fails. If some extra height is available, it can usually be traded for airspeed or gliding distance when needed.

Simply stated, altitude is more essential to safety after takeoff than excess airspeed. On the other hand, trying to gain height too fast in the takeoff can also be very dangerous because of control problems. If the airplane has just become airborne and the airspeed is at or below $V_{MC}$ when an engine fails, the pilot could avoid a serious accident by retarding both throttles immediately. If this action is not taken immediately, the pilot will be unable to control the airplane.

Consequently, the pilot should always keep one hand on the control wheel (when not operating hand controlled nose steering) and the other hand on the throttles throughout the takeoff roll. The airplane should remain on the ground until adequate speed is reached so that a smooth transition to the proper climb speed can be made. THE AIRPLANE SHOULD NEVER LEAVE THE GROUND BEFORE $V_{MC}$ IS REACHED. Preferably, $V_{MC} + 5$ knots should be attained.

If an engine fails before leaving the ground, it is advisable to discontinue the takeoff and STOP. If an engine fails after lift-off, the pilot will have to decide immediately whether to continue flight, or to close both throttles and land. However, waiting until the engine failure occurs is not the time for the pilot to plan the correct action. The action has to be planned before the airplane is taxied onto the runway. The plan of action must consider the density altitude, length of the runway, weight of the airplane, and the airplane’s accelerate/stop distance, and accelerate/go distance under these
conditions. Only on the basis of these factors can the pilot decide what course to follow if an engine should fail. When the flight crew consists of two pilots, the pilot in command will brief the second pilot on what course of action will be taken should the need arise.

To reach a safe single-engine maneuvering altitude as safely and quickly as possible, the climb with all engines operating has to be made at the proper airspeed. That speed should provide for:

- Good control of the airplane in case an engine fails.
- Quick and easy transition to the single-engine best rate-of-climb speed if one engine fails.
- A fast rate of climb to attain an altitude that permits adequate time for analyzing the situation and making decisions.

To make a quick and easy transition to the single-engine best rate-of-climb speed in case an engine fails, the pilot should climb at a speed greater than \( V_{YSE} \). If an engine fails at less than \( V_{YSE} \), it would be necessary for the pilot to lower the nose to increase the speed to \( V_{YSE} \) in order to obtain the best climb performance. If the airspeed is considerably less than this speed, it might be necessary to lose valuable altitude to increase the speed to \( V_{YSE} \). Another factor to consider is the loss of airspeed that may occur because of erratic pilot technique after a sudden, unexpected power loss. Consequently, the normal initial two-engine climb speed should not be less than \( V_Y \).

In summary, the initial climb speed with both engines operating should permit an attainment of a safe single-engine maneuvering altitude as quickly as possible. In the event of a sudden power loss on one engine, it should also provide time to roll 5 to 8° of bank into the operative engine for good control capabilities, identify and feather inoperative engine, and establish \( V_{YSE} \). The only speed that meets all of these requirements for a normal takeoff is the best rate-of-climb speed (\( V_Y \)) with both engines operating.

**ACCELERATE/STOP DISTANCE**

The accelerate/stop distance is the total distance required to accelerate the multiengine airplane to a specified speed, and assuming failure of an engine at the instant that speed is attained, to bring the airplane to a stop on the remaining runway.
To determine accelerate/stop distance for takeoff, a pilot has to consider the runway length, field elevation, density altitude, and the airplane's gross weight. (For simplification purposes, the following additional factors will not be discussed here: obstruction, height, headwind component, runway slope, and runway contaminants, such as rubber, soot, water, ice, and snow.)

Using the chart in Figure 14-5 and with a temperature of 40 °F, a calm wind at a pressure altitude of 7,586 feet, a gross weight of 4,570 pounds, and all engines operating, the airplane being flown requires 4,400 feet to accelerate to 66 KIAS and then be brought to a stop.

The most critical time for a one-engine inoperative condition in a multiengine airplane is during the 2 or 3-second period immediately following lift-off while the airplane is accelerating to climb-out speed. Although most multiengine airplanes are controllable at a speed close to the single-engine minimum control speed, the performance is often so far below optimum that continued flight following takeoff might be marginal or impossible.

If one engine fails prior to reaching $V_{m,c}$, there is no choice but to close both throttles and bring the airplane to a stop. If engine failure occurs just after lift-off, the pilot has to decide immediately to land or to continue the takeoff and accelerate to $V_{YSE}$, if that particular airplane has single-engine climb capability.

To determine climb performance, a pilot has to consider the field elevation, density altitude, obstruction height, and the airplane's gross weight. Climb performance is based on conditions specified on the chart in Figure 14-6. If these conditions are not met after lift-off, the airplane may not climb as depicted in the chart.

In this example, using the chart in Figure 14-6 with a temperature of 50 °F, at a pressure altitude of 10,000 feet, and a gross weight of 4,570 pounds, two-engine rate of climb would be 1,200 FPM
versus one-engine rate of climb of 100 FPM.

If the decision is made to continue the takeoff, the airplane has to be able to gain altitude with one engine inoperative. This requires acceleration to $V_{YSE}$ if obstacles are not involved, or to $V_{XSE}$ if obstacles are a factor. At high density altitudes and at gross weight, a successful continuation of the takeoff is extremely improbable.

![Figure 14-6.—Climb performance.](image)

The flight paths illustrated in Figure 14-7 indicate an area of decision. An engine failure in this area demands an immediate decision. Beyond this decision area, the airplane, within the limitations of single-engine climb performance, can usually be maneuvered to a landing at the departure airport.

![Figure 14-7.—Area of decision.](image)

**PROPELLER FEATHERING**

When an engine fails in flight, the movement of the airplane through the air tends to keep the propeller rotating, much like a windmill. Since the failed engine is no longer delivering power to the propeller to produce thrust, but instead is absorbing energy to overcome friction and compression of the engine, the drag of the windmilling propeller is significant and causes the airplane to yaw toward
the failed engine. [Figure 14-8] Most multiengine airplanes are equipped with full feathering propellers to minimize that yawing tendency.

![Figure 14-8. — Windmilling propeller creates drag.](image)

The blades of a feathering propeller may be positioned by the pilot to such a high angle that they are streamlined in the direction of flight. In this feathered position, the blades act as powerful brakes to assist engine friction and compression in stopping the windmilling rotation of the propeller. This is of particular advantage in case of a damaged engine, since further damage caused by a windmilling propeller can be eliminated, and a feathered prop creates the least possible drag on the airplane and reduces the yawing tendency. As a result, multiengine airplanes are easier to control in flight when the propeller of an inoperative engine is feathered.

Feathering of propellers for training and checkout purposes should be performed only when conditions, altitudes, and locations allow a safe landing on an established airport in the event of difficulty in unfeathering the propeller.

**USE OF TRIM TABS**

The trim tabs in a multiengine airplane serve the same purpose as in a single-engine airplane, but their function is usually more important to safe and efficient flight. This is because of the greater control forces, weight, power, asymmetrical thrust with one engine inoperative, range of operating speeds, and range of center-of-gravity location. In some multiengine airplanes, it taxes the pilot's strength to overpower an improperly set elevator trim tab on takeoff or go-around. Many fatal accidents have occurred when pilots took off or attempted a go-around with the airplane trimmed full nose up for the landing configuration. Therefore, prompt retrimming of the elevator trim tab in the event of an emergency go-around from a landing approach is essential to the success of the flight. Multiengine airplanes should be retrimmed in flight for each change of attitude, airspeed, power setting, and loading. Without such changes, constant application of firm forces on the flight controls is necessary to maintain any desired flight attitude.

**PRE-FLIGHT PREPARATION**

The increased complexity of multiengine airplanes demands the conduct of a more systematic inspection of the airplane before entering the cockpit, and the use of a more complete and appropriate checklist for each ground and flight operation. Preflight visual inspections of the exterior of the airplane should be conducted in accordance with the manufacturer's operating manual. The procedures set up in these manuals usually provide for a comprehensive inspection, item by item in an orderly sequence, to be covered on a complete check of the airplane. The transitioning pilot should have a thorough briefing in this inspection procedure, and should understand the reason for
checking each item.

**CHECKLIST**

All multiengine airplanes are provided with checklists, which can be very brief or extremely comprehensive. A pilot, who desires to operate a multiengine airplane safely, should use the checklist pertinent to that particular airplane. A checklist is normally divided under separate headings for common operations, such as preflight, before starting, starting, before takeoff, takeoff, cruise climb, cruise, descent, in range, before landing, landing, system malfunctions, and emergency procedures including single-engine operations. Multiengine airplanes have many more controls, switches, instruments, and indicators. Failure to position or check any of these items may have more serious results than would a similar error in a single-engine airplane. Only definite procedures, systematically planned and executed, can ensure safe and efficient operation. The cockpit checklist provided by the manufacturer should be used, with only those modifications made necessary by subsequent alterations or additions to the airplane and its equipment.

In airplanes that require a copilot, or in which a second pilot is available, it is a good practice for the second pilot to read the checklist. The pilot in command should check each item by actually touching the control or device and repeating the instrument reading or prescribed control position in question, under the careful observation of the pilot calling out the items on the checklist. [Figure 14-9] Even when a copilot is not present, the pilot should form the habit of touching, pointing to, or operating each item as it is read from the checklist. In the event of an inflight emergency, the pilot should be sufficiently familiar with emergency procedures to instinctively take immediate action to prevent more serious situations. However, as soon as circumstances permit, the emergency checklist should be reviewed to ensure that all required items have been checked.

![Figure 14-9.—Teamwork in a multiengine airplane.](image)

**TAXIING**

Although ground operation of multiengine airplanes may differ in some respects from the operation of single-engine airplanes, the taxiing procedures also vary somewhat between those airplanes with a nosewheel and those with a tailwheel-type landing gear. With either of these landing gear arrangements, the difference in taxiing multiengine airplanes that is most obvious to a transitioning pilot is the capability of using power differential between individual engines to assist in directional control.

Tailwheel-type multiengine airplanes are usually equipped with tailwheel locks that can be used to advantage for taxiing in a straight line especially in a crosswind. The tendency to weathervane can also be neutralized to a great extent in these airplanes by using more power on the upwind engine,
with the tailwheel lock engaged and the brakes used as necessary.

On nosewheel-type multiengine airplanes, the brakes and throttles are mainly used to control the momentum, and steering is done principally with the steerable nosewheel. The steerable nosewheel is usually actuated by the rudder pedals, or in some airplanes by a separate hand operated steering mechanism.

No airplane should be pivoted on one wheel when making sharp turns because this can damage the landing gear, tires, and even the airport pavement. All turns should be made with the inside wheel rolling, even if only slightly.

Brakes may be used to start and stop turns while taxiing. When initiating a turn, the brakes should be used cautiously to prevent overcontrolling the turn. Brakes should be used as lightly as practicable while taxiing to prevent undue wear and heating of the brakes and wheels, and possible loss of ground control. When brakes are used repeatedly or constantly, they tend to heat to the point that they may either lock or fail completely. Also, tires may be weakened or blown out by extremely hot brakes. Abrupt use of brakes in multiengine, as well as single-engine airplanes is evidence of poor pilot technique; it not only abuses the airplane, but may even result in loss of control.

Due to the greater weight of multiengine airplanes, effective braking is particularly essential. Therefore, as the airplane begins to move forward when taxiing is started, the brakes should be tested immediately by depressing each brake pedal. If the brakes are weak, taxiing should be discontinued and the engines shut down. Looking outside the cockpit while taxiing becomes more important in multiengine airplanes. Since these airplanes are usually somewhat heavier, larger, and more powerful than single-engine airplanes, they often require more time and distance to accelerate or stop, and provide a different perspective for the pilot. While it is usually not necessary to make S-turns to observe the taxiing path, additional vigilance is necessary to avoid obstacles, other aircraft, or bystanders.

NORMAL TAKEOFFS

There is virtually little difference between a takeoff in a multiengine airplane and one in a single-engine airplane. The controls of each class of airplane are operated the same; the multiple throttles of the multiengine airplane normally are treated as one compact power control and can be operated simultaneously with one hand.

In the interest of safety, it is important that the pilot have a plan of action to cope with engine failure during takeoff. In a multi-pilot crew, the flying pilot should brief the crew on his or her plan of action for normal and abnormal procedures and their individual responsibilities. This briefing consists of at least the following: minimum control speed (\(V_{MC}\)), rotation speed (\(V_{R}\)), lift-off speed (\(V_{LOF}\)), single-engine best rate-of-climb speed (\(V_{YSE}\)), all-engine best rate-of-climb speed (\(V_{Y}\)), and what procedures will be followed if an engine failure occurs prior to \(V_{MC}\) and after \(V_{MC}\). The multiengine pilot’s primary concern on all takeoffs is the attainment of the single-engine minimum control speed plus 5 knots prior to lift-off. Until this speed is achieved, directional control of the airplane in flight may be impossible after the failure of an engine, unless power is reduced immediately on the operating engine. If an engine fails before the single-engine minimum control speed is attained, THE PILOT HAS NO CHOICE BUT TO CLOSE BOTH THROTTLES, ABANDON THE TAKEOFF, AND DIRECT COMPLETE ATTENTION TO BRINGING THE AIRPLANE TO A SAFE STOP ON THE GROUND.

The multiengine pilot’s second concern on takeoff is the attainment of the best rate-of-climb speed
(VY) in the least amount of time. This is the airspeed that will provide the greatest rate of climb with both engines operating. In the event of an engine failure, the single-engine best rate-of-climb speed must be held. This will provide the best rate of climb when operating with one engine inoperative and propeller feathered (if possible), or the slowest rate of descent with the proper bank angle toward the operating engine. When takeoff is made over obstructions, the best angle-of-climb speed should be maintained until the obstacles are passed then the best rate of climb maintained.

The single-engine minimum control speed and the single-engine best rate-of-climb speed are published in the Airplane Flight Manual (AFM) and/or Pilot’s Operating Handbook (POH). If the crew consists of two pilots, the flying pilot will brief the other pilot on takeoff procedures prior to takeoff. Otherwise, a single pilot operator should mentally review the emergency procedures before takeoff.

After runup and the “Before Takeoff” checks have been completed, the airplane should be taxied into takeoff position and aligned with the runway.

Next, both throttles should be advanced simultaneously to takeoff power, and directional control maintained by the use of the steerable nosewheel and the rudder. Brakes should be used for directional control only during the initial portion of the takeoff roll when the rudder and steerable nosewheel are ineffective. During the initial takeoff roll, the engine instruments should be monitored.

As the takeoff progresses, flight controls should be used, as necessary, to compensate for wind conditions. Follow the manufacturer’s recommended rotation speed (VR) or lift-off speed (VLOF). If speeds are not published, use a minimum speed of VMC plus 5 knots before lift-off. After lift-off, the airplane should be allowed to accelerate to the all-engine best rate-of-climb speed (VY). If an engine should fail, the airplane will immediately lose airspeed and this will allow a buffer between VYSE and VY.

The landing gear may be raised as soon as practicable with a positive rate of climb, but not before reaching the point from which a safe landing can no longer be made on the remaining portion of the runway. The flaps (if used) should be retracted as directed in the AFM/POH.

**CROSSWIND TAKEOFFS**

Crosswind takeoffs are performed in multiengine airplanes in basically the same manner as those in single-engine airplanes. During the initial takeoff roll, less power may be used on the downwind engine to overcome the tendency of the airplane to weathervane. Full power should be applied to both engines as the airplane accelerates to a speed where rudder control is effective. The airplane should accelerate to a slightly higher-than-normal takeoff speed, and then a positive lift-off should be made to prevent possible settling back to the runway while drifting. When clear of the ground, a coordinated turn should be made into the wind to correct for drift.

**SHORT-FIELD OR OBSTACLE CLEARANCE TAKEOFF**

If it is necessary to take off over an obstacle or from a short field, the procedures should be altered slightly. For example, the initial climb speed that should provide the best angle of climb for obstacle clearance is VX rather than VY. However, VX in some multiengine airplanes is below VMC. In this case, if the climb was made at VX and a sudden power failure occurred on one engine, the pilot would not be able to control the airplane unless power was reduced on the operating engine. This would create an impossible situation because it would not be likely that the airplane could clear an obstacle with
one engine inoperative and the other at some reduced power setting. In any case, if an engine fails and the climb is to be continued over an obstacle, $V_{XSE}$ must be established if maximum performance is to be obtained.

Generally, the short-field or obstacle clearance takeoff will be much the same as a normal takeoff using the manufacturer’s recommended flap settings, power settings, and speeds. However, if the published best angle-of-climb speed ($V_X$) is less than $V_{MC} + 5$, then it is recommended that no less than $V_{MC} + 5$ be used.

During the takeoff roll as the airspeed reaches the best angle-of-climb speed, or $V_{MC} + 5$, whichever is higher, the airplane should be rotated to establish a pitch attitude that will cause the airplane to lift off and climb at that specified speed. At an altitude of approximately 50 feet or after clearing the obstacle, the pitch attitude can be lowered gradually to allow the airspeed to increase to the all-engine best rate-of-climb speed. Upon reaching safe maneuvering altitude, the airplane should be allowed to accelerate to normal or en route climb speed and the power controls reduced to the normal climb power settings.

**STALLS**

As with single-engine airplanes, the pilot should be familiar with the stall and minimum controllability characteristics of the multiengine airplane being flown. The larger and heavier airplanes have slower responses in stall recoveries and in maneuvering at slow speeds due to their greater weight. The practice of stalls in multiengine airplanes should be performed at altitudes sufficiently high to allow recoveries to be completed at least 3,000 feet above the ground or as recommended by the manufacturer.

It usually is inadvisable to execute stalls in multiengine airplanes because of their relatively high wing loading; therefore, practice should be limited to approaches to stalls with recoveries initiated at the first physical indication of an approaching stall. As a general rule, stalls in multiengine airplanes are not necessarily violent or hazardous.

The pilot should become familiar with approaching stalls entered with various flap settings, power settings, landing gear positions, and bank angles. It should be noted that the extension of the landing gear will cause little difference in the stalling speed, but it will cause a more rapid loss of speed in approaching to a stall.

For power-off stalls, the airplane can be configured for landing. After a rate of descent is established that is consistent with landing, power should be reduced to or near idle. This usually results in a level attitude stall.

Power-on stalls should be entered with both engines set at approximately 65 percent power. Takeoff power may be used after slowing to lift-off airspeed. Stalls in airplanes with relative low power loading using maximum climb power usually result in an excessive nose-high attitude and make the recovery more difficult.

Because of possible loss of control, stalls with one engine inoperative or at idle power and the other engine developing effective power, should not be practiced by applicants for multiengine class ratings. The same procedures used in the recognition and avoidance of stalls of single-engine airplanes apply to stalls in multiengine airplanes. The transitioning pilot has to be familiar with the characteristics that announce an approaching stall, the indicated airspeed at which it occurs, and the proper procedure
for recovery.

The increase in pitch attitude for stall entries should be gradual to prevent momentum from carrying the airplane into an abnormally high nose up attitude with a resulting deceptively low indicated airspeed at the time the stall occurs. It is recommended that the rate-of-pitch change result in a 1-knot-per second decrease in airspeed. In all stall recoveries, the controls should be used very smoothly, avoiding abrupt pitch changes. Because of high gyroscopic stresses, this is particularly true in airplanes with extensions between the engines and propellers.

**EMERGENCY DESCENT**

When it is necessary to descend as rapidly as feasible, such as in the case of an inflight fire, follow the manufacturer’s recommended procedures. When specific procedures are not published, the following procedures may be used and modified, as required.

1. Props  
   Max RPM  
2. Throttles  
   Closed  
3. Airspeed  
   Max Gear Down Speed or Max Flap Approach Speed (whichever is lower)  
4. Landing Gear  
   Down  
5. Flaps  
   Approach

The maneuvering speed (VA) may be used as descent airspeed but should not be higher than maximum gear down speed or flap approach speed if flaps are used. During practice emergency descents, careful consideration should be given to the operating temperature of the engines. Rapid descents with throttles closed will cause the engines to cool rapidly and possibly cause cylinder damage. In practice, some power should be left on to prevent the engines from cooling rapidly.

![Figure 14-10.—Normal two-engine approach and landing.](image)

**APPROACHES AND LANDINGS**

Multiengine airplanes characteristically have steeper gliding angles because of their relatively high wing loading, and greater drag of wing flaps and landing gear when extended. For this reason, power is normally used throughout the approach to shallow the approach angle and prevent a high rate of sink.

The accepted procedure for making stabilized landing approaches is to reduce the power to a predetermined setting during the arrival descent, so the appropriate landing gear extension speed will
be attained in level flight as the downwind leg of the approach pattern is entered.

[Figure 14-10] With this power setting, the extension of the landing gear will further reduce the airspeed to the desired traffic pattern airspeed. The manufacturer’s recommended speed should be used throughout the pattern. When practicable, the speed should be compatible with other air traffic in the traffic pattern. When within the maximum speed for flap extension, the flaps may be partially lowered, if desired, to aid in reducing the airspeed to traffic pattern speed. The angle of bank should normally not exceed 30° while turning onto the legs of the traffic pattern.

The landing checklist should be completed by the time the airplane is on base leg so that the pilot may direct full attention to the approach and landing. In a power approach, the airplane should descend at a stabilized rate, allowing the pilot to plan and control the approach path to the point of touchdown. Further extension of the flaps and slight adjustment of power and pitch should be accomplished, as necessary, to establish and maintain a stabilized approach path. Power and pitch changes during approaches should in all cases, be smooth and gradual. The airspeed of the final approach should be as recommended by the manufacturer. If a recommended speed is not furnished, the airspeed should not be less than the single-engine best rate-of-climb speed (VYSE) until the landing is assured. This is the minimum speed a single-engine go-around can be made if necessary. **IN NO CASE SHOULD THE APPROACH SPEED BE LESS THAN THE CRITICAL ENGINE INOPERATIVE MINIMUM CONTROL SPEED.** If an engine should fail suddenly and it is necessary to make a go-around from a final approach at less than this speed, a loss of control could occur. As a rule of thumb, after the wing flaps are extended the final approach speed should be gradually reduced to 1.3 times the power-off stalling speed (1.3 VSO).

The roundout or flare should be started at a sufficient altitude to allow a smooth transition from the approach to the landing attitude. The touchdown should be smooth, with the airplane touching down on the main wheels and in a tail-low attitude, with or without power as desired. Although airplanes with nosewheels should touch down in a tail-low attitude, it should not be so low as to drag the tail on the runway. On the other hand, since the nosewheel is not designed to absorb the impact of the full weight of the airplane, level or nose-low attitudes must be avoided.

Directional control on the rollout should be accomplished primarily with the rudder and the steerable nosewheel, with discrete use of the brakes applied only as necessary for crosswinds or other factors.

**CROSSWIND LANDINGS**

Crosswind landing procedures in multiengine airplanes are similar to those in single-engine airplanes. The only significant difference lies in the fact that because of the greater weight, more positive drift correction must be maintained before the touchdown.

The two basic methods of making crosswind landings, the slipping approach (wing low) and the crabbing approach, may be combined. These are discussed in the chapter on Approaches and Landings.

The essential factor in all crosswind landing procedures is touching down without drift, with the heading of the airplane parallel to its direction of motion. This will result in minimum side loads on the landing gear.
SHORT-FIELD LANDING

Short-field landing procedures are similar to those in a normal approach and landing. Approach with full flaps at the recommended short-field approach speed. If a recommended speed is not furnished, after landing is assured and the wing flaps are extended, a rule of thumb is 1.2 x \( V_{SO} \), but not less than \( V_{MC} \) for safety. Immediately after touchdown, raise the flaps, apply the back-elevator pressure and apply brakes.

GO-AROUND PROCEDURE

The complexity of multiengine airplanes makes a knowledge of and proficiency in emergency go-around procedures particularly essential for safe piloting. The emergency go-around during a landing approach is inherently critical because it is usually initiated at a very low altitude and airspeed with the airplane’s configuration and trim adjustments set for landing.

Unless absolutely necessary, the decision to go around should not be delayed to the point where the airplane is ready to touch down. [Figure 14-11] The more altitude and time available to apply power, establish a climb, retrim, and set up a go-around configuration, the easier and safer the maneuver becomes. When the pilot has decided to go around, immediate action should be taken without hesitation, while maintaining positive control and accurately following the manufacturer’s recommended procedures.

Figure 14-11.—Make a timely decision to go around or land.

Go-around procedures vary with different airplanes, depending on their weight, flight characteristics, flap and retractable gear systems, and flight performance. Specific procedures must be learned by the transitioning pilot from the AFM/POH, which should always be available in the cockpit.

There are several general go-around procedures that apply to most airplanes.

- When the decision to go around is reached, takeoff power should be applied immediately and the descent stopped by adjusting the pitch attitude to avoid further loss of altitude.
- The flaps should be retracted in accordance with the procedure prescribed in the AFM/POH.
- After a positive rate of climb is established, the landing gear should be retracted, best rate-of-climb airspeed (\( V_Y \)) obtained and maintained, and the airplane trimmed for this climb. Any remaining flaps are then retracted. The procedure for a normal takeoff climb should then be followed.

At any time the airspeed is faster than the flaps-up stalling speed, the flaps may be retracted completely without losing altitude if simultaneously the angle of attack is increased sufficiently. At slow airspeeds, retracting the flaps prematurely or suddenly can cause a stall or an unanticipated loss of altitude. Rapid or premature retraction of the flaps should be avoided on go-arounds, especially
when close to the ground, because of the careful attention and exercise of precise pilot technique necessary to prevent a sudden loss of altitude. Generally, retracting the flaps only halfway or to the specified approach setting decreases the drag a relatively greater amount than it decreases the lift.

The AFM/POH should be consulted regarding landing gear and flap retraction procedures. In some installations, simultaneous retraction of the gear and flaps may increase the flap retraction time, and full flaps create more drag than the extended landing gear.

ENGINE INOPERATIVE EMERGENCIES

The operating and flight characteristics of multiengine airplanes with one engine inoperative are excellent. Multiengine airplanes can be controlled and maneuvered safely as long as sufficient airspeed is maintained. However, to utilize the safety and performance characteristics effectively, the pilot has to have a sound understanding of the single-engine performance and the limitations resulting from an unbalance of power.

A pilot checking out for the first time in any multiengine airplane should practice and become thoroughly familiar with the control and performance problems that result from the failure of one engine during any flight condition. Practice should be continued as long as the pilot engages in flying a multiengine airplane so that corrective action will be instinctive, and the ability to control airspeed, heading, and altitude will be retained.

The feathering of a propeller should be demonstrated and practiced during training in all airplanes equipped with propellers that can be feathered and unfeathered safely in flight. If the airplane used is not equipped with feathering propellers, one engine should be secured (shut down) in accordance with the procedures in the AFM/POH. All training in multiengine airplanes involving engine shut down, regardless if the propeller can be feathered or not, must be accomplished at an altitude that will allow for a safe landing at an established airport if an actual emergency develops.

ENGINE INOPERATIVE PROCEDURES

The following procedures are recommended to develop in the transitioning pilot the habit of using proper procedures and proficiency in coping with an inoperative engine.

At a safe altitude (minimum 3,000 feet above terrain) and within landing distance of a suitable airport, an engine may be shut down with the mixture control or fuel selector. At lower altitudes, however, shut down should be simulated by reducing power by adjusting the throttle to the zero thrust setting. The following procedures should then be followed:

1. Fly the airplane Maintain control, VYSE, heading, bank into operating engine.
2. Power Increase or leave as set for takeoff.
3. Drag (reduce) Props, gear, or flaps - pilots choice based on conditions & airplane.
4. Identify Idle foot inoperative engine.
5. Verify With throttle or other means.
6. Feather Inoperative engine propeller.
7. Checklist Start from the top.
In all cases, the airplane manufacturer’s recommended procedure for single-engine operation should be followed. The general procedures listed above are not intended to replace or conflict with any procedure established by the manufacturer of any airplane. It can be used effectively for general training purposes and to emphasize the importance of maintaining aircraft control and reducing drag.

The pilot must be proficient in the control of heading, airspeed, and altitude; in the prompt identification of a power failure; and in the accuracy of shutdown and restart procedures as prescribed in the AFM/POH.

There is not a better way to develop skill in single-engine emergencies than by continued practice. The fact that the procedures of single-engine operation are mastered thoroughly at one time during a pilot’s career is no assurance of being able to cope successfully with a single-engine emergency unless review and practice are continued. Some engine inoperative emergencies may be so critical that there may not be a safety margin for lack of skill or knowledge. It is essential that the multiengine pilot take proficiency training periodically from a competent flight instructor.

The pilot should practice and demonstrate the effects (on single-engine performance) of various configurations of gear, flaps, and both; the use of carburetor heat; and the failure to feather the propeller on an inoperative engine. Each configuration should be maintained at single-engine best rate-of-climb speed long enough to determine its effect on the climb (or sink) achieved. Prolonged use of carburetor heat, if equipped, at high-power settings should be avoided.

**VMC DEMONSTRATIONS**

Every multiengine airplane checkout should include a demonstration of the airplane’s single-engine minimum control speed. The single-engine minimum control speed given in the AFM/POH or other manufacturer’s published limitations is determined during the original airplane certification under conditions specified in the CofA. These conditions are normally not duplicated during pilot training or testing because they consist of the most adverse situations for airplane-type certification purposes. Prior to a pilot checkout, a thorough discussion of the factors affecting single-engine minimum control speed is essential.

The VMC demonstrations should be performed at an altitude that will allow the maneuver to be completed no lower than 3,000 feet above ground level (AGL) or the manufacturer’s recommended altitude, whichever is higher. One demonstration should be made while holding the wings level and the ball centered, and another demonstration should be made while banking the airplane at least 5° toward the operating engine to establish zero sideslip. These maneuvers will demonstrate the single-engine minimum control speed for the existing conditions and will emphasize the necessity of banking into the operative engine. An attempt should not be made to duplicate VMC, as determined for airplane certification.

After the propellers are set to high revolutions per minute (RPM), the landing gear is retracted, and the flaps are in the takeoff position, the airplane should be placed in a climb attitude and an airspeed at or above the intentional one-engine inoperative speed (VSSE). With both engines developing as near rated takeoff power as possible, power on the critical engine (usually the left) should then be reduced to idle (windmilling, not shut down). After this is accomplished, the airspeed should be reduced at approximately 1 knot per second with the elevators until directional control can no longer be maintained. At this point, recovery should be initiated by simultaneously reducing power sufficiently on the operating engine and reducing the angle of attack by lowering the nose of the
airplane to accelerate to \( V_{SE} \). Under no circumstances should an attempt be made to fly at a speed below \( V_{MC} \) with only one engine operating. Should indications of a stall occur prior to reaching this point, recovery should be initiated immediately by reducing the angle of attack and power on the operating engine to control roll and increase airspeed to \( V_{SE} \). The demonstration should then be accomplished with the rudder travel limited at a higher airspeed.

**ENGINE FAILURE BEFORE LIFT-OFF (REJECTED TAKEOFF)**

When an engine fails during the takeoff roll before becoming airborne, it is advisable to close both throttles immediately and employ maximum braking, while maintaining directional control. In training, the recommended procedure to simulate an engine failure on takeoff is to close the mixture on one engine before 50 percent \( V_{MC} \). This provides a safety factor for the instructor pilot and more time for the training pilot to make a proper decision. If the training pilot fails to recognize the emergency promptly, the instructor pilot can close the mixture on the running engine and bring the airplane safely to a stop. Also, during training, to save wear and tear on the airplane, the training pilot may announce maximum braking rather than actually using maximum braking when remaining runway length is adequate.

**ENGINE FAILURE AFTER LIFT-OFF**

If after becoming airborne an engine should fail prior to having reached the single-engine best rate-of-climb speed (\( V_{YSE} \)), the same procedure used for engine failure before lift-off should be followed. This is recommended because an immediate landing is usually inevitable because of the altitude loss required to increase the speed to \( V_{YSE} \).

The pilot must have determined before takeoff what altitude, airspeed, and airplane configuration must exist to permit the flight to continue in the event of an engine failure. The pilot should also be ready to accept the fact that if engine failure occurs before these required factors are established, both throttles must be closed and the situation treated the same as an engine failure on a single-engine airplane. If it has been predetermined that the single-engine rate of climb under existing circumstances will be at least 50 FPM at 1,000 feet above the airport, and that at least the single-engine best angle-of-climb speed has been attained, the pilot may decide to continue the takeoff. If the airspeed is below the single-engine best angle-of-climb speed (\( V_{XSE} \)) and the landing gear has not been retracted, the takeoff should be abandoned immediately.

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**Figure 14-12.—Engine failure during takeoff procedures.**
If the single-engine best angle-of-climb speed \( (V_{XSE}) \) has been obtained and the landing gear is in the retract cycle, the pilot should climb at the single-engine best angle-of-climb speed \( (V_{XSE}) \) to clear any obstructions. The pilot should hold 5 to 8° of bank into the operating engine and stabilize the airspeed at the single-engine best rate-of-climb speed \( (V_{YSE}) \) while identifying, verifying, and feathering the inoperative engine propeller, then, retract the flaps. When the decision is made to continue the flight, the single-engine best rate-of-climb speed should be attained and maintained with the inoperative engine feathered. [Figure 14-12] Even if altitude cannot be maintained, it is best to continue to hold that speed because it would result in the slowest rate of descent and provide the most time for executing the emergency landing. After the decision is made to continue flight and a positive rate of climb is attained, the landing gear should be retracted as soon as practical.

If the airplane is barely able to maintain altitude and airspeed, a turn requiring a bank greater than 15° should not be attempted. When such a turn is made under these conditions, both lift and airspeed will decrease. It is advisable to continue straight ahead whenever possible, until reaching a safe maneuvering altitude and \( V_{YSE} \). At that time, a steeper bank may be made safely in either direction. There is nothing wrong with banking toward a “inoperative” engine if a safe speed and zero sideslip are maintained.

When an engine fails after becoming airborne, the pilot should hold the heading with the rudder and simultaneously roll into a bank of 5 to 8° toward the operating engine. The more bank used initially will lower \( V_{MC} \) and help maintain control with no or very little climb performance. With the airplane under control and the proper airspeed attained for climb, the bank angle can be reduced to establish zero slip to increase climb performance. Without a yaw indicator, 2° to 3° of bank and one-half ball deflection is recommended for maximum performance.

The best way to identify the inoperative engine is to note the direction of yaw and the rudder pressure required to maintain heading. To counteract the asymmetrical thrust, extra rudder pressure will have to be exerted on the operating engine side. To aid in identifying the failed engine, some pilots use the expression “Dead Foot Dead Engine.” Never rely on tachometer or manifold pressure readings to determine which engine has failed. After power has been lost on an engine, the tachometer will often indicate the correct RPM and the manifold pressure gauge will indicate the approximate atmospheric pressure or above.

Experience has shown that the biggest problem is not in identifying the inoperative engine, but rather in the pilot’s actions after the inoperative engine has been identified. In other words, a pilot may identify the inoperative engine and then attempt to shut down the wrong one, resulting in no power at all. To avoid this mistake, the pilot should verify that the inoperative engine has been identified by retarding the throttle of the suspected engine before shutting it down.

When demonstrating or practicing procedures for engine failure on takeoff, the feathering of the propeller and securing of the engine should be simulated rather than actually performed, so that the engine may be available for immediate use if needed. All other settings should be made just as in an actual power failure.

**ENGINE FAILURE EN ROUTE**

Normally, when an engine failure occurs while en route in cruising flight, the situation is not as critical as when an engine fails on takeoff. With the more leisurely circumstances, the pilot should take time to determine the cause of the failure and to correct the condition, if possible. If the condition cannot
be corrected, the single-engine procedure recommended by the manufacturer should be accomplished and a landing made as soon as practical.

A primary error during engine failure is the pilot's tendency to perform the engine inoperative identification and shutdown too quickly, resulting in improper identification or incorrect shutdown procedures. The element of surprise generally associated with actual engine failure may result in confused and hasty reactions.

When an engine fails during cruising flight, the pilot's main problem is to maintain sufficient altitude to be able to continue flight to the nearest suitable point of landing. This is dependent on the density altitude, gross weight of the airplane, and elevation of the terrain and obstructions. When the airplane is above its single-engine service ceiling, altitude will be lost. The single-engine service ceiling is the maximum density altitude at which the single-engine best rate-of-climb speed will produce 50 FPM rate of climb. This ceiling is determined by the manufacturer on the basis of the airplane's maximum gross weight, flaps and landing gear retracted, the critical engine inoperative, and the propeller feathered. Although engine failure while en route in normal cruise conditions may not be critical, it is a recommended practice to add maximum available power to the operating engine before securing or shutting down the failed engine. If it is determined later that maximum available power on the operating engine is not needed to maintain altitude, it is a simple matter to reduce the power. Conversely, if maximum available power is not applied, the airspeed may decrease much farther and more rapidly than expected. This condition could present a serious performance problem, especially if the airspeed should drop below $V_{YSE}$.

The altitude should be maintained if it is within the capability of the airplane. If the airplane is not capable of maintaining altitude with an engine inoperative under existing circumstances, the airspeed should be maintained at the single-engine best rate-of-climb speed ($V_{YSE}$) so as to conserve altitude as long as possible to reach a suitable landing area. After the failed engine is shut down and everything is under control (including heading and altitude), it is recommended that the pilot communicate with the nearest ground facility to let them know the flight is being conducted with one engine inoperative. Federal Aviation Administration (FAA) facilities are able to give valuable assistance if needed, particularly when the flight is conducted under instrument flight rules (IFR) or a landing is to be made at a tower controlled airport. Good judgment dictates that a landing be made at the nearest suitable airport rather than continuing flight.

During single-engine practice using zero thrust power settings, the engine may cool to temperatures considerably below the normal operating range. This factor requires caution when advancing the power at the termination of single-engine practice. If the power is advanced rapidly, the engine may not respond and an actual engine failure may be encountered. This is particularly important when practicing single-engine approaches and landings. A good procedure is to slowly advance the throttle to approximately one-half power, then allow it to respond and stabilize before advancing to higher power settings. This procedure also results in less wear on the engines.

Restarts after feathering require the same amount of care, primarily to avoid engine damage. Following the restart, the engine power should be maintained at the idle setting or slightly above until the engine is sufficiently warm and is receiving adequate lubrication.

**ENGINE INOPERATIVE APPROACH AND LANDING**

Essentially, a single-engine approach and landing is the same as a normal approach and landing.
Long, flat approaches with high-power output on the operating engine and/or excessive threshold speed that results in floating and unnecessary runway use should be avoided. Due to variations in the performance and limitations of many multiengine airplanes, a specific flight path or procedure can not be proposed that would be adequate in all single-engine approaches. In most multiengine airplanes, a single-engine approach can be accomplished with the flight path and procedures almost identical to a normal approach and landing. The multiengine manufacturers include a recommended single-engine landing procedure in the AFM/POH.

During the checkout, the transitioning pilot should perform approaches and landings with the power of one engine set to simulate the drag of a feathered propeller (zero thrust), or if feathering propellers are not installed, the throttle of the simulated failed engine set to idle. With the inoperative engine feathered or set to zero thrust, normal drag is considerably reduced, resulting in a longer landing roll. Allowances should be made accordingly for the final approach and landing.

The final approach speed should not be less than $V_{YSE}$ until the landing is assured; thereafter, it should be at the speed commensurate with the flap position until beginning the roundout for landing. Under normal conditions, the approach should be made with full flaps; however, neither full flaps nor the landing gear should be extended until the landing is assured. When more drag is required, the landing gear should be the first option if it does not conflict with the manufacturer’s recommended procedure. With full flaps, the approach speed should be $1.3 \, V_{SO}$ or as recommended by the manufacturer.

The pilot should be particularly judicious in lowering the flaps. Once they have been extended, it may not be possible to retract them in time to initiate a go-around. Most of the multiengine airplanes are not capable of making a single-engine go-around with full flaps. Each make and model of airplane must be operated in accordance with the manufacturer’s recommended procedures.
CHAPTER 15 - AERONAUTICAL DECISION MAKING

INTRODUCTION

Throughout pilot training, safety, and good Aeronautical Decision Making (ADM) should be emphasized. Some of the basic concepts of ADM are presented in this chapter to provide an understanding of the ADM process.

GENERAL

Many aeronautical decisions are made easily—like flying on a beautiful day when the weather is perfect. However, some decisions can be more difficult—like whether to turn back when the clouds start closing in and visibility drops. When this happens, the decisions made on whether to continue the flight, turn back or deviate to an alternate airport, or fly higher or lower, will become critical to ensuring that the flight is completed safely. All too often many flights end in tragedy because of a bad decision that placed the aircraft in a situation that exceeded the capabilities of the pilot, aircraft, or both. This does not have to happen if a pilot recognizes the importance of timely decision making and takes some of the steps outlined below to ensure that he or she makes the best decisions possible under the circumstances. Most pilots usually think good judgment is only acquired through years of experience. The general aviation private pilot, who flies for pleasure or occasional personal business, will probably fly a small percentage of the hours that a professional pilot will fly over the course of a flying career. A pilot cannot rely simply upon experience as a teacher of good judgment. It is important to learn how to deal with decision making in general and to learn strategies that will lead to effective judgment in a wide variety of situations.

TYPES OF DECISIONS

It is important to recognize that there are two general types of decisions. Decisions that are tied to time constraints and those that is not. In a time constraint decision, a solution is required almost immediately. An example might be an engine failure near the ground. For the most part, a pilot is trained to recognize events like this that require immediate action. Usually, when time is not a constraint, time is available to gather information and consider alternative courses of action. For example, when planning a flight, a pilot has access to an extensive array of information sources, such as weather, airport conditions, and aircraft performance. A pilot should examine the sources until he or she is confident that all the information needed to make the flight has been examined.

A study conducted by NASA revealed that 80 percent of the errors that led to an incident occurred during the preflight phase, while the incidents occurred later during the flight.

It seems obvious that a large number of accidents and incidents could be avoided, if a pilot were to perform better preflight planning. Flight planning is similar to an open-book test in school—all the information needed is available, if a pilot knows where to look. Decision aids are tools that can be used to ensure all relevant information is considered. The appropriate flight planning, followed by the operation of the aircraft within a pilot’s capabilities, will ensure a safe flight. Good examples of decision making tools are the various checklists that are provided by the manufacturers of aircraft. There are checklist, for guiding our preflight inspection of the aircraft, starting the engine(s), setting
up the radios, and preparing for takeoff and landing. They are inexpensive, effective, and enhance safety. Checklists provide an effective means of solving the most human of frailties—forgetting. If a pilot follows a checklist, those temporary memory lapses need not have an impact on the flight. The sequence of operations and the critical information required is all recorded for a pilot to use.

**EFFECTIVENESS OF ADM**

The effectiveness of ADM and the safety of general aviation depend on several factors:

- The knowledge required to understand the situation, the information available, and the possible options.
- The skills required to execute a decision.
- Understanding how to make decisions effectively, including how to search for information and when to stop searching and choose a course of action.
- The self-awareness to recognize when hazardous attitudes are influencing decisions and possessing the self-discipline to overcome those attitudes.

The first two factors, knowledge and skills, will be addressed during the ground and flight training. The knowledge required to understand weather conditions, calculate fuel requirements, use of checklists, and other items required for flight planning will be explained. Flight instructors will also teach how to put preflight planning into action. This will start a pilot on a path toward making good aeronautical decisions based on the limitations of the aircraft, weather conditions, and the pilot's experience level. This will also help a pilot develop a positive attitude toward safety and risk management. Having a positive attitude means always considering the potential safety implications of decisions.

Progressive decision making recognizes that changes are constantly taking place, and that a pilot should be continually assessing the outcome. For example, more weather information about alternate airports will allow the pilot to judge the quality of the decision and to recognize when it is time to modify that outcome in the face of new information. A pilot with this progressive decision making strategy may make changes rapidly based on the information at hand. The pilot should continue to seek more information about the situation so the plan may be refined and modified if necessary.

Flexibility and the capability to modify actions as new information is obtained are very desirable features of decision making. What this means, in simplest terms, is always having a way out.

The other factor that was mentioned earlier that would affect the quality and safety of a pilot’s decisions is attitude. Attitude is one of those aspects of human nature that is hard to define precisely, but we know it when we see it. It is an overall approach to life. It is something in the way people talk and act that makes us think that they are reckless, safe, liberal, conservative, serious, happy-go-lucky, or any one of a number of other adjectives. They have a certain style of responding to life’s events that is relatively consistent and which they tend to apply in many situations.

Think for a moment about the stereotypical image of pilots portrayed in popular films—particularly those from several years ago. Films deal in images and an image like that is much easier to portray than the reality. There is a lot of truth to the old adage, “There are old pilots and there are bold pilots, but there are no old, bold pilots.” Flying is a wondrous adventure, but it is not the place for boldness, thrill seeking, complacence, or lack of dedication to doing the best one can.
A series of studies conducted a few years ago identified five attitudes among pilots that were particularly hazardous. These attitudes are:

- **Antiauthority**: This attitude is found in people who do not like anyone telling them what to do. Flying is governed by many regulations established for the safety of all, so pilots with this hazardous attitude may rebel against authority by deliberately breaking rules intended for safety.

- **Impulsivity**: This is the attitude of people who frequently feel the need to do something—anything—immediately. They do the first thing that comes to mind, without thinking about what the best alternative might be.

- **Invulnerability**: Many people feel that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected, but they never really feel or believe they will be personally involved. A pilot with this attitude is more likely to take chances and increase risk.

- **Macho**: A pilot who is always trying to prove that he or she is better than anyone else is thinking, “I can do it—I’ll show them.” All pilots are equally susceptible to this hazardous attitude which can lead to taking risks to impress others.

- **Resignation**: Pilots who think, “What’s the use?” do not see themselves as being able to make a great deal of difference in what happens. They blame whatever happens on luck. Instead of seeking out information and making positive decisions, they just drift along making no changes and hoping for the best.

Having these attitudes can contribute to poor pilot judgment, since they tend to push the pilot toward making decisions that involve more risk. Recognizing that these hazardous attitudes exist is the first step in neutralizing them in the decision making process. Before dismissing these attitudes as belonging to someone else, realize that everyone has these attitudes to some degree. At one time or another all pilots have acted impulsively or in a macho fashion to demonstrate their aviation skills to others.

Pilots should be aware of these attitudes and constantly examine their actions to see if they are falling prey to their influences. This will help a pilot improve the quality of his or her actions.

Developing good decision making skills will allow pilots to fly securely in the knowledge that they are controlling risk and ensuring safety. Figure 18-1 provides some useful antidotes for hazardous attitudes.

**Minimum Personal Checklist**

Proper planning will allow a pilot to make better decisions and to have a safer flight. Figure 18-2 provides a sample checklist to assist a pilot in the planning and decision making process. It can be revised and updated to meet the needs of individual pilots.

**Aircraft Performance**

Establish that you have additional performance available over that required. Consider the following:

- Gross weight
- Load distribution
- Density altitude
- Performance chart

**Aircraft Equipment**

Avionics familiar with equipment (including autopilot and GPS systems)
Figure 18-2.—Minimum personal checklists.

ENVIRONMENT

Airport Conditions
Crosswind........................................................... ___% of max POH Runway length................................................... ___% more than POH

Weather
Reports and forecasts...................................................... not more than ___ hours old in aircraft type Icing conditions.................................................. within aircraft/pilot capabilities

Weather for VFR
Ceiling Day........................................................... ___ feet Night................................................................. ___ feet Visibility Day........................................................... ___ miles Night................................................................. ___ miles

Weather for IFR
Precision Approaches Ceiling........................................................... ___ feet above min. Visibility........................................................... ___ mile(s) above min. Non-Precision Approaches Ceiling........................................................... ___ feet above min. Visibility........................................................... ___ mile(s) above min. Missed Approaches No more than........................................................... ___ before diverting Takeoff Minimums Ceiling........................................................... ___ feet Visibility........................................................... ___ mile(s)
Figure 18-2.—Minimum personal checklists.

EXTERNAL PRESSURES

Trip Planning
Allowance for delays............................................ ____ minute

Diversion or Cancellation Alternate Plans
Notification of person(s) you are meeting
Passengers briefed on diversion or cancellation plans and alternatives
Modification or cancellation of car rental, restaurant, or hotel reservations
Arrangement of alternative transportation (Airline, car, etc.)

Personal Equipment
Credit card and telephone numbers available for alternate plans
Appropriate clothing or personal needs (eye wear, medication ...) in the event of an unexpected stay