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PRINCIPLES OF FIXED WING FLIGHT

HEADQUARTERS, DEPARTMENT OF THE ARMY

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PRINCIPLES OF FIXED WING FLIGHT

PART ONE

AERODYNAMICS

CHAPTER 1

INTRODUCTION

1. Purpose

The purpose of this manual is to explain general principles concerning the operation of fixed wing aircraft in accomplishing the Army Aviation mission. The principles included are of equal importance to aviation students and rated aviation personnel.

2. Scope

Part one explains aerodynamics, or the theory of flight. Parts two through four cover the mechanics of flight maneuvers: for the beginner, to develop proficiency and instill confidence; for the experienced pilot, to provide a basis for checking aviator proficiency. Part five explains advanced methods of flying an airplane to accomplish the Army Aviation mission. A glossary lists and defines specialized terms used in this manual.

CHAPTER 2

BASIC PHYSICAL LAWS AS APPLIED TO AERODYNAMICS

Section I. PHYSICAL LAWS

3. General

An aviator need not know all basic physical laws related to aerodynamics. He must, however, have some knowledge of these laws to understand aerodynamics as applied to his aircraft and its control. This knowledge is best gained through application of basic laws to demonstrate how forces which affect the airplane or its various parts cause specific actions and reactions in flight.

4. Force, Pressure, Work, and Power

a. Force. Force is the effect of any action which changes the state of motion or position of a body; i.e., any action which tends to produce, retard, or modify motion. A force has three characteristics: magnitude, direction, and point of application. It may be referred to as a "push" or "pull," expressed in pounds, which tends to produce or prevent motion.

b. Pressure. Pressure is force per unit of area and is usually measured in pounds per square inch. For example, if the base of a suitcase has an area of 100 square inches and weighs 100 pounds, the pressure of the suitcase on the area will be 100 pounds divided by 100 square inches, or one pound per square inch.

$$\text{Pressure} = \frac{\text{Total Force}}{\text{Area Acted Upon}}\text{; or } P = \frac{F}{A}$$

c. Work. Work is the exertion of a force over a given distance, expressed in foot-pounds. If a weight of 50 pounds is raised 10 feet, 500 foot-pounds of work has been accomplished: $W = F \times D$ (50×10). This is expressed as W equals Fs, in which s stands for surface (area acted upon). The time required to do this work is not considered.

d. Power. Power is work accomplished in a given time, and can be expressed in the formula:

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} = \frac{\text{Work}}{\text{Time}}\text{; or } P = \frac{Fs}{T}$$

Power is equal to force times velocity, usually expressed in terms of horsepower. Horsepower is an arbitrary unit of power measurement, computed as being the power required to lift or move an object weighing 550 pounds one foot in one second. To illustrate, the horsepower required to move a weight of 5,000 pounds at the rate of 1000 feet per minute is 151.8 HP:

1,000 feet per minute = 16.7 feet per second.

$$\text{Horsepower} = \frac{\text{Force} \times \text{Distance}}{\text{Time} \times 550} = \frac{5{,}000 \times 16.7}{1 \times 550} = 151.8\ HP$$

5. Energy

Energy is the ability to do work. It is measured in the same units as work and may be considered as stored work. The three types of energy are *potential, kinetic* and *pressure* energy.

a. Potential Energy. Potential energy is that energy in a body which by virtue of its mass and position is the product of force or weight multiplied by the height of the body above a reference line. A weight of 50 pounds suspended 10 feet above the floor is said to possess 500 foot-pounds of potential energy.

b. Kinetic Energy. Kinetic energy refers to work that has been done by imparting velocity to an object. The object is said to possess kinetic energy because, in slowing up or stopping an object, work is accomplished and may be expressed as potential energy expended or converted. A pile driver is an example of both potential and kinetic energy. When the weight or hammer of the pile driver is in position, it has potential energy. When the hammer drops, the potential energy is converted into kinetic energy. An airplane moving through the air has kinetic energy because of its motion.

c. Pressure Energy. Pressure energy may be of either the potential or kinetic type. If it is not performing work, it is of the potential type; e.g., compressed air in an air hose. As the air is released into a tire it becomes kinetic energy by inflating the tire. Another example of kinetic pressure energy is the pressure on the bottom side of a moving wing which forces the wing up and into the area of lower pressure above the wing.

6. Laws of Motion

Fundamental of the physical laws are Newton's three laws of motion.

a. Inertia. Newton's first law (inertia) states that a body at rest tends to remain at rest and a body in motion tends to remain in motion at the same speed and in the same direction until affected by some external force. Nothing in nature starts or stops without an outside force to bring about or prevent this motion. Hence, the force with which a body offers resistance to change is called the force of inertia.

b. Acceleration. Newton's second law (acceleration) asserts that the force required to produce a change in motion of a body is directly proportional to the mass of the body and rate of its change in velocity. Acceleration is the change in velocity per unit of time. It may increase or decrease, although *deceleration* is commonly used to indicate a decrease.

c. Action—Reaction. Newton's third law (action-reaction) states that to every action there is an equal and opposite reaction. If a force acts to change the state of motion of a body, the body offers a resistance equal and directly opposite to the force.

7. Speed and Velocity

Speed and velocity are frequently used interchangeably, but in aerodynamics they are distinguished. Speed refers to the distance traveled in a certain time and is determined by distance traveled in an interval of time *regardless of direction.* Velocity is speed *in a certain direction* and is determined by the amount of change in position in a straight line in a certain time interval. Direction of velocity may be up, down, east, west, or in any direction; but the direction must be stated.

8. Acceleration

The acceleration of an object, regardless of weight, falling freely through space, is caused by the pull of gravity with a rate of acceleration approximately 32 feet per second per second. Galileo roughly showed proof of this by dropping weights off the Leaning Tower of Pisa, and the physical law is called Galileo's Principle.

Section II. VECTORS

9. Vector and Scalar Quantities

A vector quantity is a graphic representation of a force and shows both the magnitude and direction of the force. Velocity, having both magnitude and direction, is a vector quantity. It specifies a certain amount of speed in a certain direction. Speed is called a *scalar* quantity (point of a scale) since it represents only magnitude. When an object is being acted upon by two or more forces, the combined effect of these forces may be represented by the use of vectors. In representing a vector quantity, a directed line segment with an arrow at the end is used. The arrow indicates the direction in which the force is acting. The length of the line segment in relation to a given scale represents the magnitude of the vector. The vector, therefore, is drawn in relation to a reference line. The magnitude is drawn to whatever scale is most convenient to the specific problem (fig. 1).

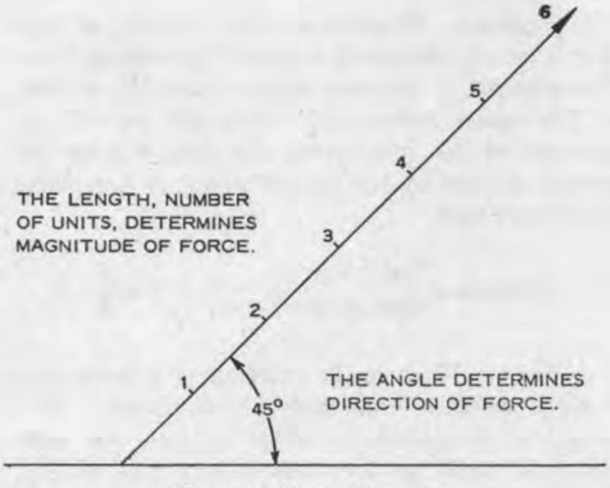


Figure 1. Vector diagram.

10. Vector Solutions

Individual force vectors are useful in analyzing conditions of flight. In the air, the chief concern is with the resultant, or combined effects, of the several component forces acting on an airplane. Three methods of solving for resultants are given below.

a. Parallelogram. A parallelogram contains a number of vectors, and lines are drawn parallel to these vectors to determine the resultant mean. In the case of two tugboats pulling a barge with equal force at 90° to each other, the barge will move forward in a direction that is a mean to the direction of both (fig. 2).

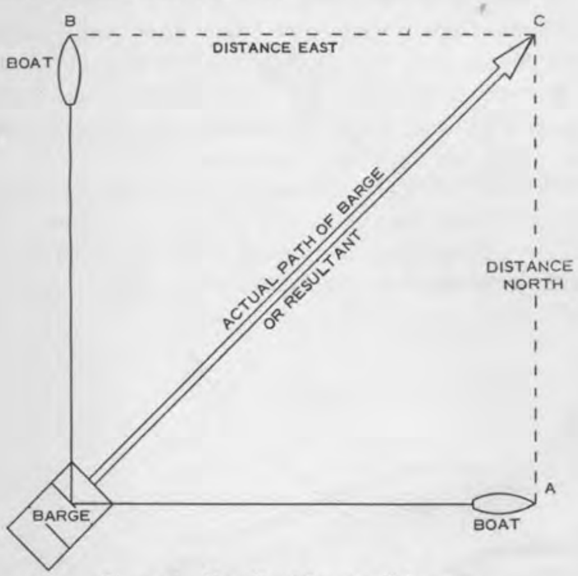


Figure 2. Resultant by parallelogram.

b. Triangle of Velocities. A triangle of velocities is formed by drawing two vectors and connecting them with a resultant line or vector. In this way, calculations may be made for drift and ground speed. In figure 3, an aircraft is traveling with a true airspeed of 100 knots. The pilot desires to make good a true course of 90°. Wind direction is from northeast at 30 knots. By drawing a vector for each of these known quantities and drawing a connecting line between the ends, a resultant mean is determined. Point A (fig. 3) is the point of beginning both the wind source and course line. The wind vector ends at D. From this point a line is drawn at a length equivalent to the true airspeed and connecting with the course line at any reachable point. The line AE is measured as the resulting ground speed. The angle between the meridian and line DE indicates the direction heading of the airplane in making good the desired track.

c. Polygon Vector Solution. When more than two forces are acting in different directions, the resultant may be found by using a polygon vector solution. This solution is shown in figure 4, in which one force is acting at 090° with a force of 180 pounds. A second force is acting at 045° with a force of 90 pounds, while the third force is acting at an angle of 315° with a force of 120 pounds. To solve for the resultant, draw (fig. 4) the first vector from a point beginning (O) and follow it with the remaining vectors consecutively (A, B, and C). At the ending of the final vector (C), the resultant is drawn from the point of start (O) to the ending of the final vector, and the resultant determined.

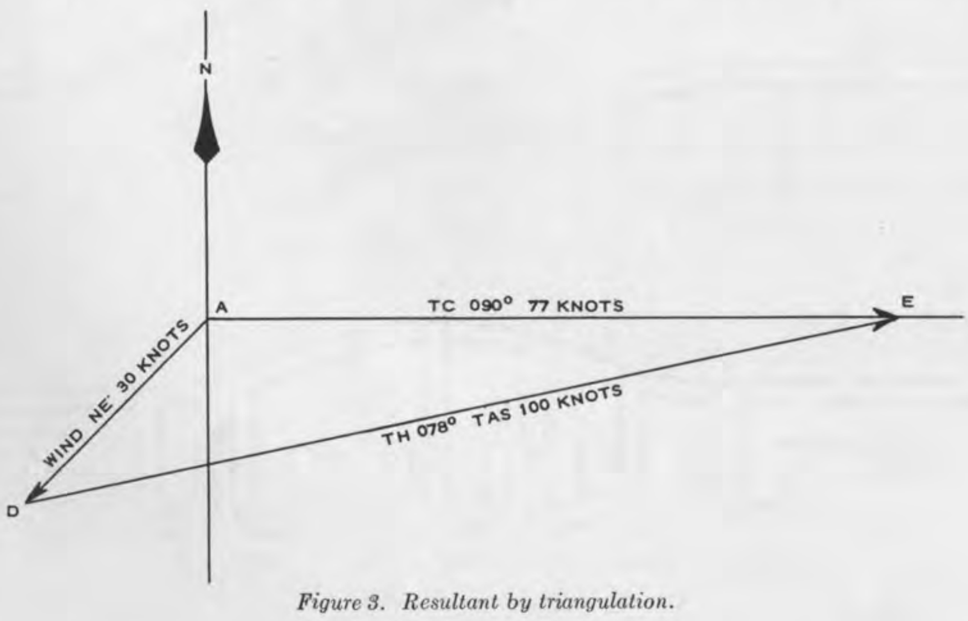


Figure 3. Resultant by triangulation.

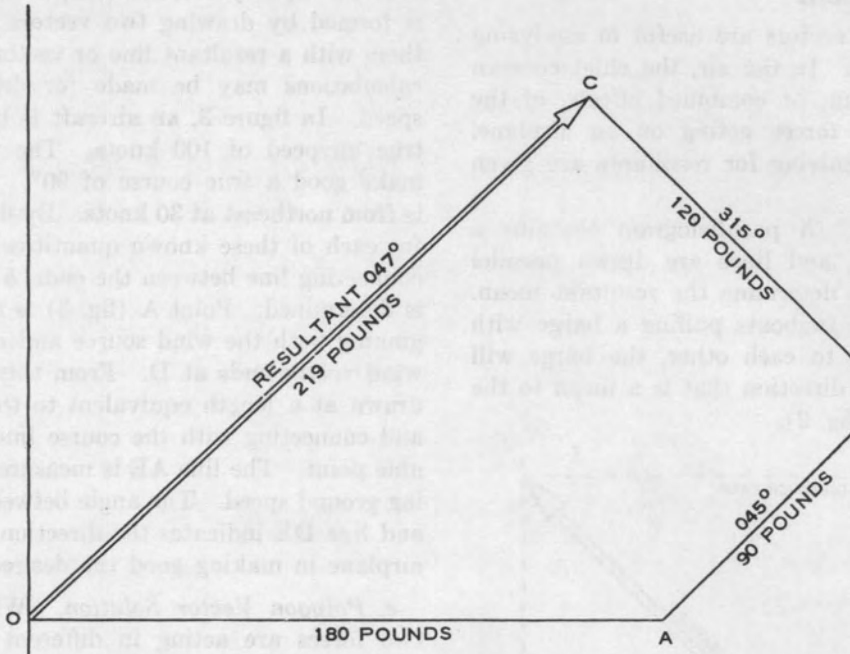


Figure 4. Resultant by polygon.

CHAPTER 3

PRINCIPLES OF AIRFOILS AND FORCES ACTING ON AN AIRCRAFT IN FLIGHT

Section I. PRINCIPLES OF AIRFOILS

11. Meaning of Aerodynamics

Aerodynamics is the science of the action of air on an object. It is further defined as that branch of dynamics dealing with the motion of air and other gases; with the forces acting upon an object in motion through the air; or with an object which is stationary in a current of air. Aerodynamics normally treats of the action resulting from the movement of an object through the air. In effect, aerodynamics is concerned with three distinct parts—the object, the movement, and the air. These parts may be defined as the airplane, the relative wind, and the atmosphere, respectively.

12. Bernoulli's Theorem

The scientist Bernoulli discovered that the total energy of a system remains unchanged (constant). If one element of the energy system increases, another element decreases to counterbalance it. Thus, Bernoulli found that when the energy of motion increases, the energy of pressure decreases. This theorem is readily seen by use of a venturi tube (fig. 5). If the same amount of air that enters the tube is also going to leave it, then the velocity of the air must increase while passing the neck of the venturi. As the velocity increases, the air has less time in which to push against the sides of the tube,

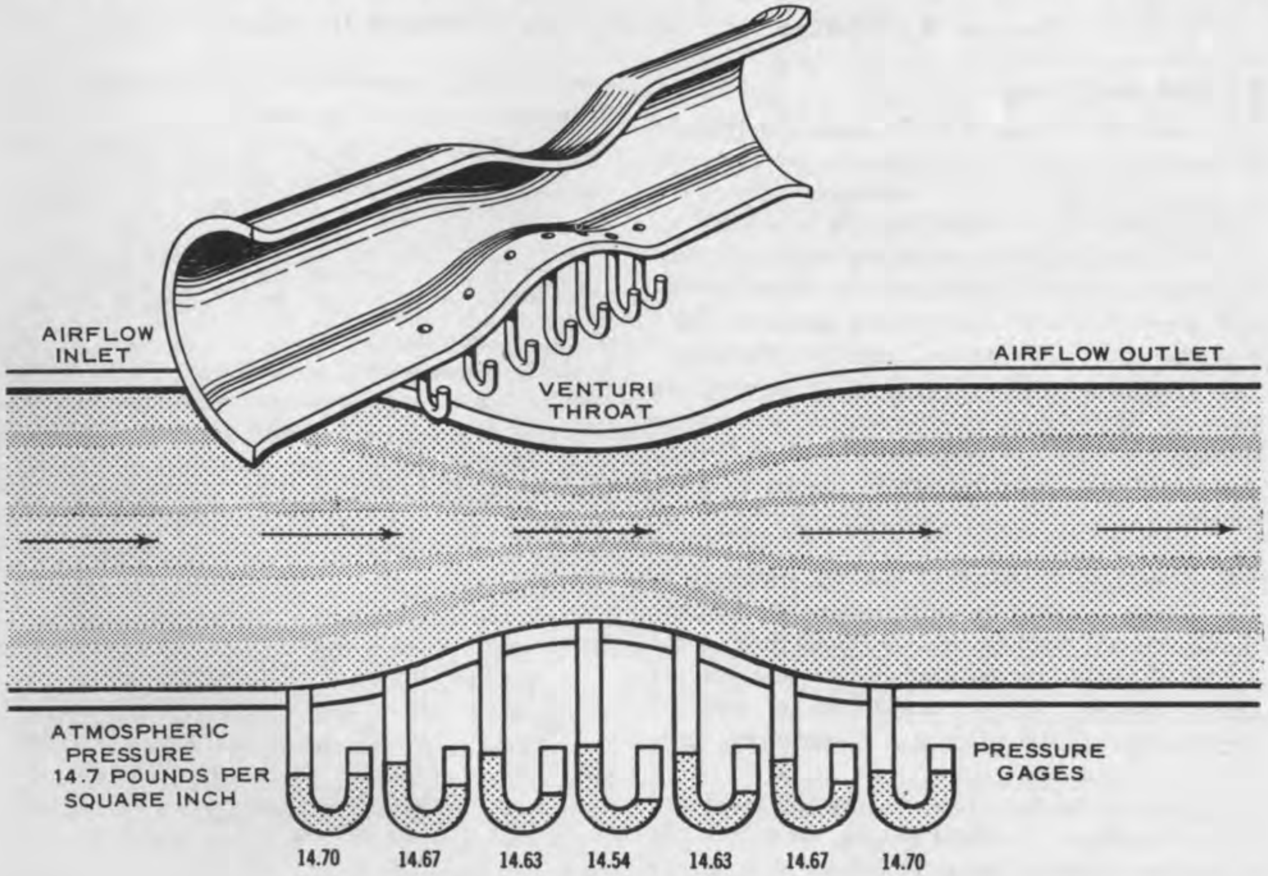


Figure 5. Venturi tube.

thereby exerting less pressure. Since there is no change of velocity of the air about the open end of the tube, there is no change in pressure. The differential pressure on the ends of the tubes attached to the venturi causes the fluid to move toward the end of the tube that has the least pressure.

13. Design of an Airfoil

The upper and lower surfaces of an airfoil may differ in total length, the upper surface usually being the longer. Air passing over the upper surface of an airfoil must increase its velocity since it has a greater distance to travel. This can be compared to the lower half of a venturi tube (fig. 6). Therefore, pressure on top of the airfoil is decreased. The air passing the bottom of the airfoil has less distance to travel. The velocity of the air then is not as great as over the top; therefore, more pressure is present on the lower surface. Also, the lower surface in normal flight moves at an angle to the relative wind causing the wind, or air, to strike the surface and produce some impact pressure. The reduced pressure above and increased pressure beneath the airfoil produces the "resultant aerodynamic force."

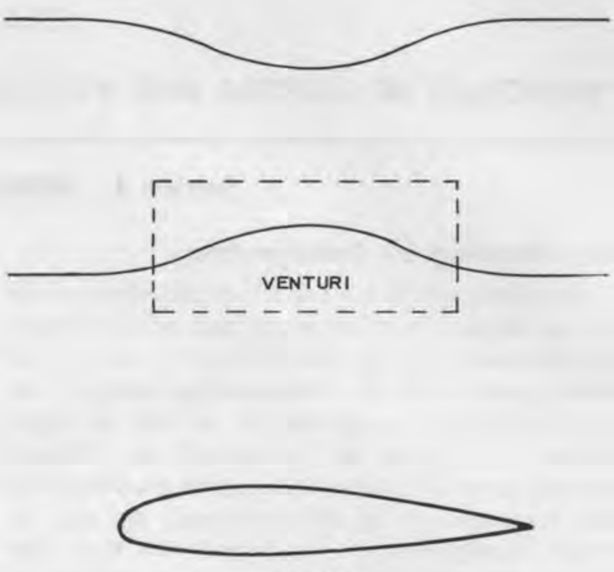


Figure 6. Comparison of airfoil and venturi tube.

Section II. FORCES ACTING ON AN AIRCRAFT IN FLIGHT

14. Lift and Weight

a. Lift is a component of the total aerodynamic force acting on an airfoil which acts perpendicular to the relative wind. This force acts through the center of lift, which is the mean of all centers of pressure. Its magnitude varies proportionately with airspeed, air density, shape and size of the airfoil, and angle of attack. In straight and level flight it is equal and opposite to the weight component.

b. Weight is the force exerted by an airplane from the pull of gravity. It acts on an airplane through the center of gravity. The magnitude of this force changes only with a change in gross weight.

15. Thrust and Drag

a. Thrust is the force which moves an airplane through the air. It acts on an airplane through the center of thrust and is produced by the engine-driven propeller. Thrust varies with the speed of the propeller and the amount of power which turns it.

b. Drag is the force produced by the resistance of the air offered an object passing through it. It acts on an airplane through the center of drag. In unaccelerated flight it is equal and opposite to thrust. Drag may be divided into two main types —induced drag and parasite drag.

(1) Induced drag is that drag created (induced) by the creation of lift. The low pressure area above the airfoil and the air striking the lower surface of the airfoil would cause that airfoil to move backward and upward if suddenly released from its restraint.

(2) Parasite drag is that drag created by the entire airplane, excluding induced drag. It is caused by protrusions, such as hinges and landing gear, roughness of the surfaces of the airplane and impact of air

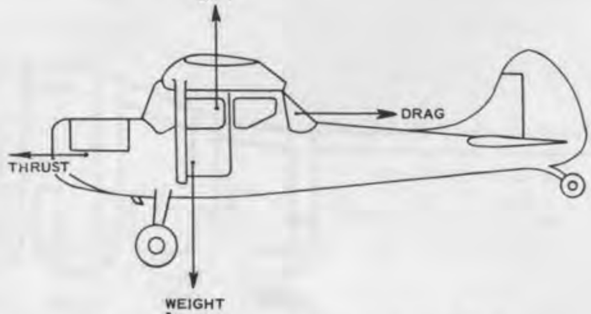


Figure 7. Forces and their centers in flight.

on the frontal surfaces of parts of the airplane.

16. Centrifugal Force

Centrifugal force is produced by any object moving in a circular path. The force acts toward the outside of the circle or turn. It reacts on an airplane during all turns, regardless of the plane of the turn. Centrifugal force, when acting on an airplane, usually acts in opposition to lift.

Section III. FACTORS AFFECTING LIFT AND DRAG

17. Equations

Important factors influencing lift and drag are the shape and area of the airfoil, angle of attack, air density, and airspeed. A change in any of these factors affects the relationship of lift and drag which is best seen through use of the following equations:

a. Lift Equation.

$L = C_L \cdot \frac{D}{2} \cdot A \cdot V^2$, where:

L = lift
C_L = coefficient of lift
D = density of the air in slugs per cubic foot
A = total wing area in square feet
V = airspeed in feet per second

b. Drag Equation.

$d = C_D \cdot \frac{D}{2} \cdot A \cdot V^2$, where:

d = drag
C_D = coefficient of drag
D = density of the air in slugs per cubic foot
A = total wing area in square feet
V = airspeed in feet per second

Note. C_L is the amount of weight in pounds that one square foot of wing area will lift at a speed of one foot per second, and C_D is the amount of drag in pounds that one square foot of wing area will create at a speed of one foot per second. These values for various angles of attack of a given airfoil are found in wind tunnel tests.

18. Effect of Airfoil Shape and Angle of Attack

a. Two factors that most affect the coefficient of lift and coefficient of drag of an airfoil are the shape, as established by the manufacturer, and the angle of attack, which is controlled by the pilot. As the length of the upper camber is increased, lift is also increased, to a certain point. If the length is further increased, the airflow will separate from the airfoil, causing a loss of lift. But as lift is increased, so is drag. Therefore, the airfoil is designed to produce the most lift and least drag at the designed normal weight and speed.

b. By changing the angle of attack, the pilot, in effect, changes the upper camber of the airfoil and the differential pressure. This may be done by changing the pitch attitude or by the use of flaps. Figure 8 shows how lift and drag increase with the angle of attack. The third line shows how the lift-drag ratio varies with different angles of attack.

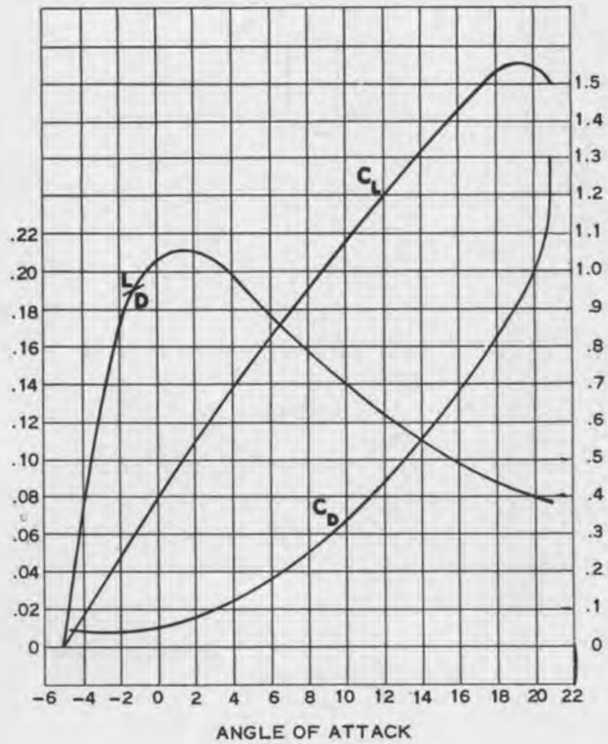


Figure 8. Lift-drag chart.

19. Effect of Air Density, Wing Area, and Airspeed

a. Density is the weight of an object per unit volume and differs from pressure in that pressure is force per unit area. Density is directly affected by temperature, pressure, and humidity. Since density affects lift—temperature, pressure, and humidity also affect lift. An increase in temperature or humidity, or a decrease in pressure, will cause density to decrease, thereby causing lift to decrease. To sustain level flight when these conditions exist, the pilot must increase either the angle of attack or the airspeed since these are the only two factors he can control.

b. Wing area affects lift and drag directly. If two wings have the same proportion and airfoil sections, a wing with an area of 200 square feet will lift twice as much at the same angle of attack and airspeed as a wing with an area of 100 square feet.

c. In the lift formula, lift varies as the square of velocity. Therefore, an airplane traveling at 200 mph has four times as much lift as one traveling at 100 mph so long as other factors remain constant. If airspeed is changed, then some other factor must be inversely changed to maintain the same lift. The only other factor a pilot can control is the angle of attack. This may be changed by pitch attitude or flaps. For a given airspeed and weight, there is only one angle of attack that will maintain level flight.

CHAPTER 4

FLIGHT CONTROLS AND PRINCIPLES OF FLIGHT

Section I. FLIGHT CONTROLS

20. General

Each flight control change affects the attitude of the aircraft and controls movement about an axis. Airplanes have three axes about which they rotate and three flight controls to effect rotation about these axes.

21. Operation of Controls

For desired control, the pilot should use pressures, not actual stick movements. All controls should be coordinated while flying; they are discussed separately here only for clarity.

a. The *elevator* is the control which causes the airplane to rotate about its *lateral* axis. This is called *pitch.* When forward pressure is applied to the stick (A, fig. 9), the elevator moves downward causing the tail to move upward and the nose downward. When back pressure is applied to the stick (B, fig. 9), the elevator moves upward causing the tail to move downward and the nose upward.

b. The *rudder* is the control which causes the airplane to rotate about its *vertical* axis. This is

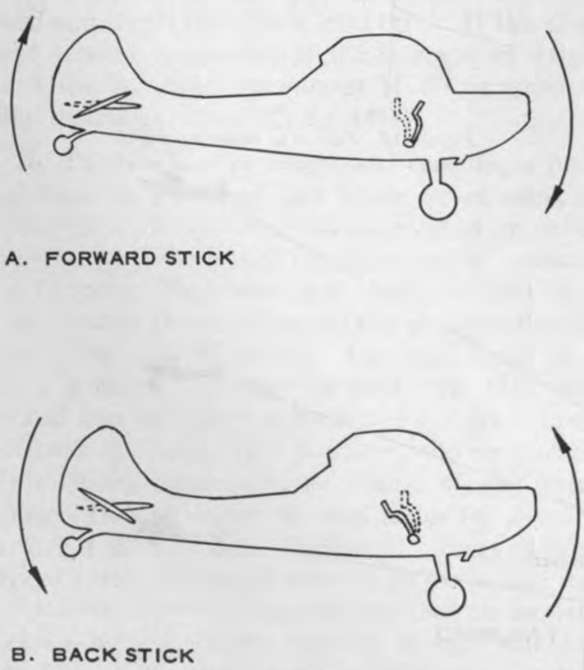


Figure 9. Elevator control.

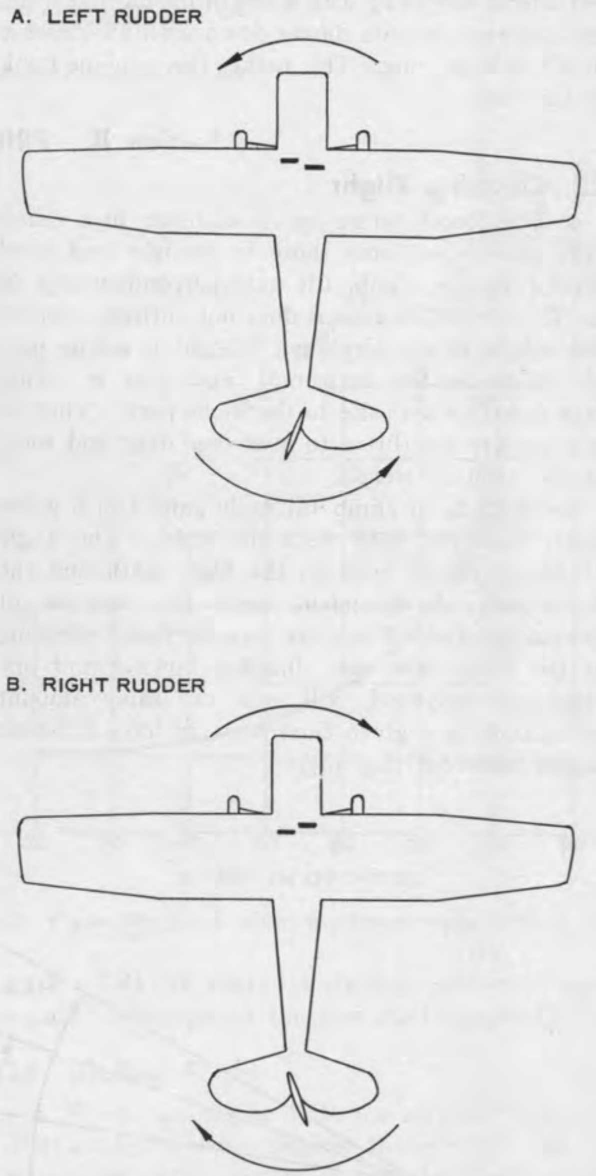


Figure 10. Rudder control.

called *yaw*. When pressure is applied to the right rudder pedal, the rudder moves to the right (B, fig. 10), causing the tail to move to the left and the nose to move to the right. When pressure is applied to the left rudder pedal, the rudder moves to the left (A, fig. 10), causing the tail to move to the right and the nose to the left.

c. The *ailerons* control the rotation about the *longitudinal* axis of the airplane. This is called *roll*. When right pressure is applied to the stick (A, fig. 11) the right aileron moves up, causing a loss of lift on that wing, and the left aileron moves down, causing an increase of lift on that wing. This makes the airplane bank to the right. When left pressure is applied to the stick (B, fig. 11), the left aileron moves up with a loss of lift on that wing, and the right aileron moves down with an increase in lift on that wing. This makes the airplane bank to the left.

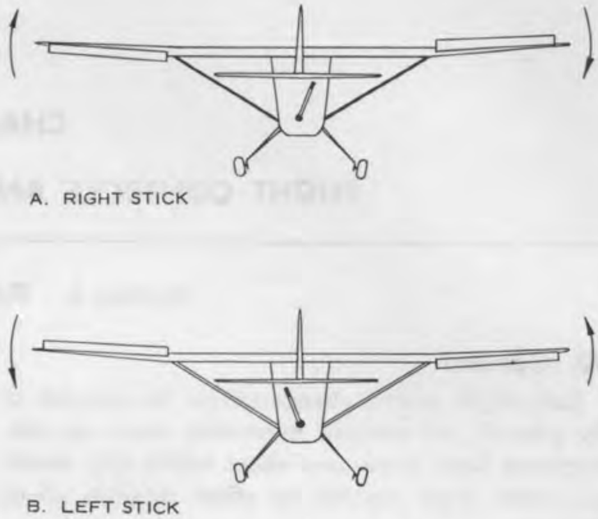


Figure 11. Aileron control.

Section II. PRINCIPLES OF FLIGHT

22. Climbing Flight

a. The forces acting on an airplane in a climb differ somewhat from those in straight and level flight. In the climb, lift acts perpendicularly to the flight path, so that it does not entirely support the weight of the airplane. Weight is acting perpendicular to the horizontal, and drag is acting in a direction opposite to the flight path. Thus, it is necessary for thrust to overcome drag and some of the airplane weight.

b. The rate of climb (altitude gained in a given time) does not vary with the wind. The angle of ascent (angle between the flight path and the horizontal) is dependent upon the amount of ground covered. Therefore, two airplanes climbing at the same rate, one climbing upwind and one climbing downwind, will gain the same amount of altitude in a given time but will have different angles of ascent (fig. 13).

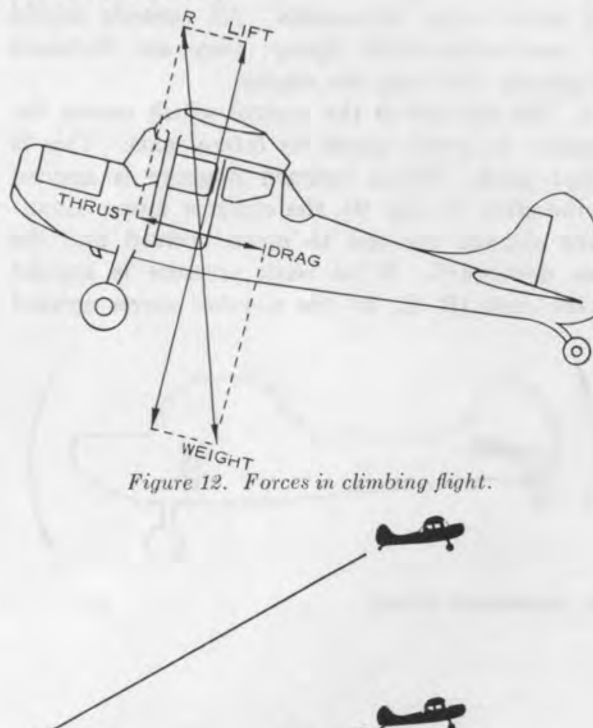


Figure 12. Forces in climbing flight.

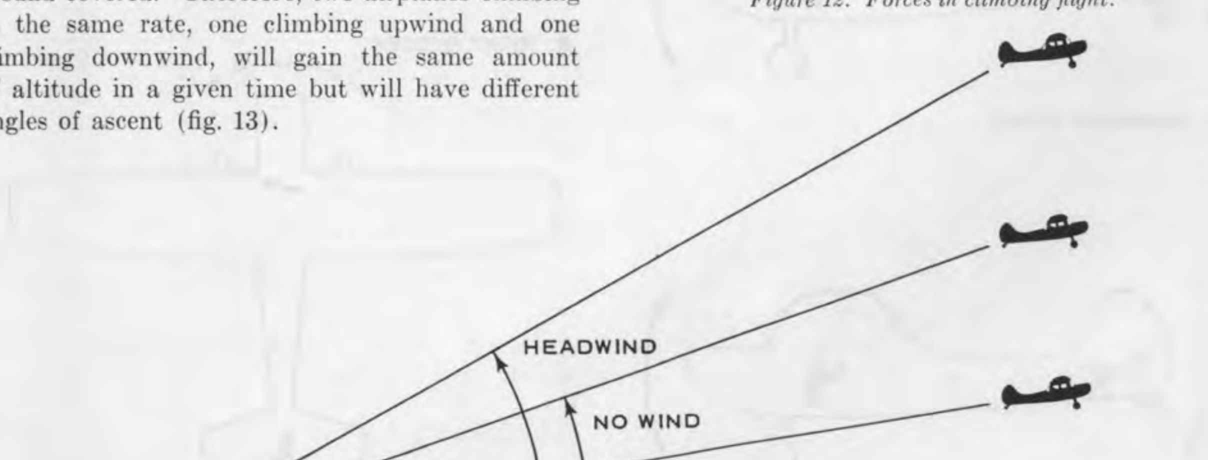


Figure 13. Effect of wind on a climb.

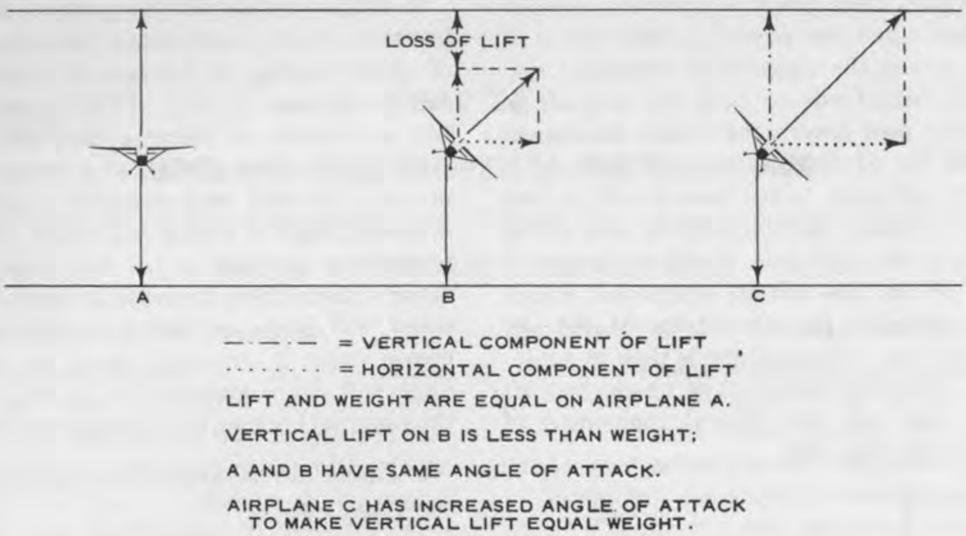


Figure 14. Horizontal and vertical components of lift.

23. Turning Flight

a. Turning flight is accomplished by changing the lift of an airplane from the vertical (A, fig. 14) toward the horizontal. This produces centrifugal force, which tends to move an object toward the outside of a turn. The resultant of weight and centrifugal force is outward and downward. This must be overcome by lift or the airplane will lose altitude (B, fig. 14). Lift has a vertical and horizontal component in the turn. The resultant of these components must equal the resultant of weight and centrifugal force for a level turn. At this time, the vertical component of lift is equal to weight and the horizontal component of lift is equal to the centrifugal force (C, fig. 14).

b. The resultant of weight and centrifugal force produces an increased load factor on an airplane. Load factor is the total load imposed on an object divided by the weight of the object and is measured in G units. The centrifugal force produced by a turn adds to the total load on the airplane, thereby increasing its load factor. The load factor in a turn is affected by angle of bank (fig. 15). Airspeed does not affect it because for a given angle of bank the rate of turn decreases with an increase in airspeed, resulting in no change of centrifugal force. In a 60° bank the load factor for any airplane is 2, regardless of airspeed. Since stalling speed varies in direct proportion to the square root of the load factor, it can be seen that an airplane with a normal stalling speed of 50 mph will stall at 70 mph in a 60° bank. (The square root of 2 G's is 1.41 G's, times the stalling speed of 50 mph, equals 70.50 mph as the new stalling speed.)

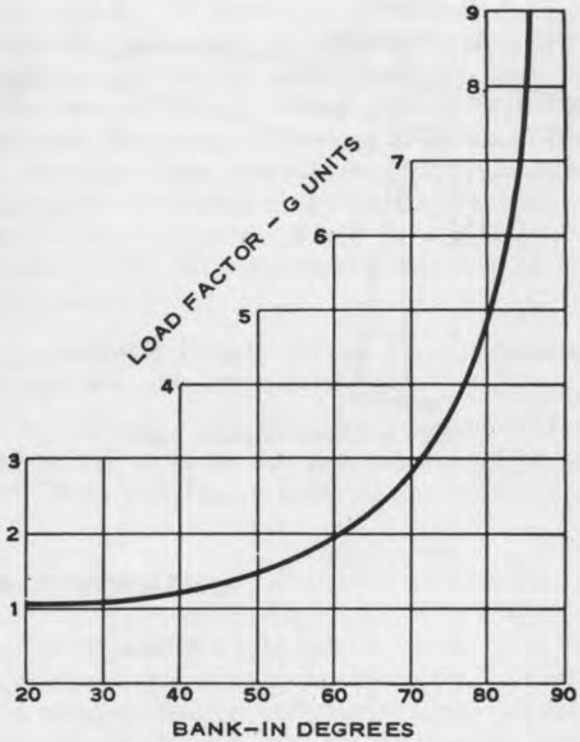


Figure 15. Load factors in various angles of bank.

24. Gliding Flight

a. When the engine fails the airplane does not drop straight down. Because the center of gravity is forward of the center of lift, the airplane will tend to nose over when power is removed. All the lift is not lost when the power is removed; it is still created unless the airspeed is extremely low. Therefore, lift still tends to hold the airplane in the air. As the nose lowers, the weight component begins to pull the airplane down. In doing so it will cause the airspeed to increase which in turn causes lift to increase. Although lift is then acting perpendicular to the flight path, it still has a vertical component. When this vertical component equals the weight component, the rate of descent and airspeed will stabilize. The airplane is then in a constant glide. The thrust resultant of weight and lift then equals drag and the vertical component of lift equals weight (fig. 16).

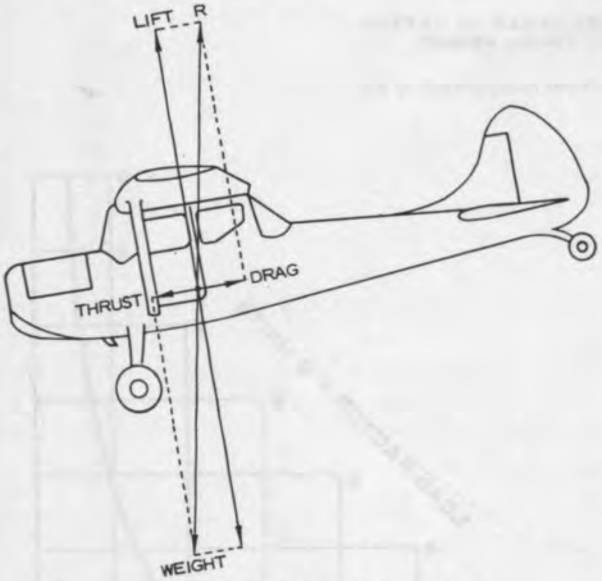


Figure 16. Forces in gliding flight.

b. If the vertical lift component should become less than weight, the airplane will increase its angle of glide, causing an increase in airspeed and resulting increase in lift. This causes the vertical lift component to increase and will once again stabilize the glide, though at a steeper angle than normal. If stick back pressure is applied, an increase in angle of attack will result, causing a corresponding increase in lift and drag. This will cause a momentary decrease in angle of glide. Airspeed will begin to dissipate causing lift to decrease until it becomes equal to weight. The glide will again stabilize but at an angle steeper than normal because the lift-drag ratio has changed.

c. Glides can be divided into three types: normal, slow, and fast.

(1) The normal glide, often called "best" glide, gives the most forward distance for the least loss of altitude. The angle of attack and resulting airspeed which will provide the greatest lift-drag ratio is used. Airspeed must vary proportionately with weight to maintain the same angle of glide; hence, the glide will remain constant regardless of weight, provided parasite drag is not changed.

(2) A slow glide is one at an airspeed slower than a normal glide. The resultant angle will be steeper than that of a normal glide.

(3) A fast glide is one at an airspeed faster than a normal glide. The resultant glide angle will be steeper than that of a normal glide.

CHAPTER 5

AIRCRAFT AND PROPELLER PERFORMANCE

Section I. AIRCRAFT PERFORMANCE

25. Factors Affecting Performance

a. Performance characteristics of an airplane are such factors as range, endurance, rate of climb, ceiling, speed, and landing and takeoff speed. These factors are affected directly by the forces of lift, weight, thrust, and drag. A change of any one of the forces will cause a variation in the other three and, accordingly, affect airplane performance.

b. The most common change of the forces acting on an airplane is a change in its weight. An increase in weight requires a corresponding increase in lift to carry the extra weight. The increased lift requires additional thrust and/or angle of attack, which correspondingly increases drag. The net result is less speed for a given power or less range for a given speed. Operational ceiling of the airplane is lowered due to the requirements for increased lift. Rate of climb is decreased since there is less reserve power available for the climb.

c. Cruise control, the scientific operation of an airplane engine to obtain maximum efficiency commensurate with the requirements of the mission, definitely affects the range and endurance of an airplane. It provides economy for the amount of fuel used during the flight and for overall engine wear.

26. Effect of Air Density on Performance

One of the most consistent and definite influences on aircraft performance is air density. Because density decreases with altitude, the air becomes thinner and causes peculiar changes in performance. At 36,000 feet air density is one-fourth that at sea level. Therefore, speed could double at this altitude and drag would remain unchanged from that at sea level at the normal speed. However, the decreased density also affects engine and propeller performance. To double the speed at 36,000 feet, twice the horsepower is required. For a given distance, even though power is doubled, only the same amount of fuel is used since speed is also doubled. The power requirement at sea level varies as the cube of the airspeed; therefore, eight times the power is required to double the speed at sea level. The advantage of high altitude flight is thus apparent. Altitude limiting factors of an airplane are—

a. Available Power. As air density decreases so does available horsepower.

b. Available Lift. The wings reach an altitude where they no longer can give sufficient lift to sustain flight with the available power.

Section II. PROPELLER PERFORMANCE

27. Propeller Design

The propeller is considered an airfoil because it creates a useful aerodynamic reaction when moved through the air. It receives its power from the engine, which causes the propeller to rotate and create propeller lift. Propeller lift is commonly called *thrust.*

a. Like all airfoils, the propeller must be designed to withstand various stresses caused by the forces acting on it. An additional force, centrifugal force, acts on the propeller constantly during use. This is caused by the rotation which tends to pull on the propeller from the hub toward the ends. The strength of this force varies proportionately with the speed of rotation. Lift derived from the rotation also produces a force on the propeller which tends to bend it. If the propeller is not capable of withstanding this bending, it might start "fluttering," setting up vibrations that could cause it to disintegrate.

b. At a constant rotational speed the tip of the propeller travels at a considerably higher speed than the section nearest the hub. Therefore, to provide symmetrical loading, the propeller is twisted in design to decrease the angle of attack from hub to tip. This will then cause the amount of lift produced along the propeller blade to remain nearly constant from the hub to the tip.

c. When there is no forward movement of the airplane, the relative wind for the propeller is determined by the direction and speed of rotation of it. As the airplane moves forward the relative wind will change, decreasing the angle of attack. All airfoils have one angle of attack which is operationally most efficient. By using a propeller on which the angle of attack can be varied as the airspeed varies, propeller efficiency can be maintained at its peak most of the time. Many types of propellers permit this. However, smaller aircraft normally do not use such a propeller, but employ a fixed-pitch propeller—its pitch or angle of attack can be changed only by changing forward speed. Fixed-pitch propellers normally fall into two categories, *high performance* and *cruise.*

(1) The high performance propeller is designed to have greater propeller efficiency with little forward speed. This will permit the engine to develop nearly maximum horsepower for short, fast takeoffs and steep climbs.

(2) The cruise propeller is designed to give greater propeller efficiency with more forward speed. This means a faster cruising airspeed with no more power. However, with little forward speed, the angle of attack is so great that the propeller and, consequently, the engine will not turn fast enough to develop full horsepower.

d. Propellers of smaller aircraft are usually attached to the engine crankshaft. But as propeller length increases, it is not always possible to have engine and propeller rotational speeds the same. An engine must be able to attain given rpm to reach maximum horsepower. This might cause the peripheral speed (tip speed) of a long propeller to be too great. To compensate for this, some propellers are geared to the engines to achieve good propeller efficiency and high engine horsepower.

e. Propellers on most multiengine airplanes have the capability of feathering: the mean blade angle can be turned parallel to the direction of flight. This is an added safety factor controlled from the cockpit by the pilot.

f. Reversible-pitch propellers are generally used on larger multiengine airplanes. This characteristic is especially helpful to shorten the ground landing roll by providing thrust in the opposite direction. It also may be used to maneuver the airplane on the ground.

g. The number of propeller blades used on an airplane is determined by the horsepower available and thrust required. Adding propeller blades is the best way to increase the surface area of the propeller. However, if too many blades are used, they follow so closely that each blade will disturb the same air: the effect is the same as a spinning tire. The result is negligible thrust.

28. Torque Effects

a. The torque reaction of the clockwise turning propeller causes an airplane tendency of rotation about the longitudinal axis to the left. Torque reaction is compensated for by wash-in on the left wing and washout on the right wing. However, this causes more drag on the left wing, which is most noticeable during takeoff.

b. Gyroscopic action, known as precession, causes the airplane to turn to the left about its vertical axis during takeoff. If a deflective force is applied to the rim of a spinning gyroscope, the resultant force is 90° ahead in the direction of rotation and in the same direction of the applied force. The propeller acts as a gyroscope and tends to precess if its axis of rotation is moved. The friction caused by the ground roll is the same as an applied force at the lowest portion of the propeller arc which will react as a force pushing on the left side of the propeller arc. It may be further increased by abruptly lifting the tail, which will cause the propeller axis to move and additional precession to occur.

c. The slipstream or "prop wash" flows behind the propeller in a corkscrew motion. With low forward speed and high propeller speed the corkscrew motion is tight and will strike the vertical tail surfaces on the left side, pushing toward the right. As forward speed increases, the corkscrew motion elongates until its effect is slight at normal cruise. The vertical stabilizer generally is offset enough to compensate for this and other effects at normal cruise.

d. Unsymmetrical loading of the propeller causes an airplane tendency to turn to the left. When in a three-point attitude, the plane of propeller rotation is at an angle with the horizontal. The downward moving blade is moving forward in the plane of rotation and the upward moving blade is moving backward in the plane of rotation. This results in a greater angle of attack on the downward moving blade than on the upward blade as forward motion starts. Consequently, more thrust is gained from the right side of the propeller arc until the plane of rotation becomes perpendicular to the flight path.

CHAPTER 6

AIRCRAFT CLASSIFICATION, CONSTRUCTION, AND STABILITY

Section I. CLASSIFICATION AND CONSTRUCTION

29. Methods of Classifying Aircraft

Aircraft may be classified by the wing, powerplant, landing gear, and purpose.

a. Wing. The number, location, and design of the wing helps classify an aircraft. There may be one, two, or three wings, although most of today's aircraft are of single wing construction. They can be further classified by the location or design of the wing. The *high-wing* airplane has the wing attached to the top of the fuselage; the *mid-wing*, perpendicularly at or near the center of the fuselage; and the *low-wing*, at the bottom of the fuselage. The wing may have the normal straight edge design; the *swept wing* design, where both are leading and trailing edges are at an angle to the longitudinal axis; or *delta wing* design, where the leading edge is swept back and the trailing edge forms the rear of the aircraft.

b. Powerplant. An aircraft may be referred to by the type of powerplant used, such as reciprocating engine or turbine engine. The reciprocating engine always uses a propeller, which may further aid in classification. A *tractor* type propeller is mounted in front of the engine; the *pusher* type propeller is located aft of the engine. The turbine engine, which does not use a propeller, is commonly referred to as the *jet type*; those which use a propeller are usually called *turboprop* type.

c. Landing Gear. There are several different types of landing gear. For land planes, they may be either *retractable* or *fixed*. *Conventional* landing gear has two main wheels, one on each side of the fuselage, and a tail wheel. *Bicycle* gear has two main wheels beneath the fuselage in tandem, and usually a balance wheel under each wing. *Tricycle* gear has two main wheels, one on each side of the fuselage, and a nose wheel. *Seaplanes* use floats or the fuselage for landing. *Amphibian* aircraft are equipped with landing gear for either land or water operations.

d. Purpose. The purpose or use for which an aircraft is designed or used will also help classify it. This classification may be *reconnaissance, observation, command, light cargo, utility,* or *trainer*. Other classifications of military aircraft are not applicable to Army aircraft.

30. Stresses

a. Structural units of an aircraft are designed to withstand various stresses while in flight and on the ground, both singly and collectively. The five types of stress are *compression, tension, bending, torsion,* and *shear*.

(1) *Compression* is the force which tends to compress, or push together, a structural part. Sitting on a chair subjects the legs of the chair to compression stress.

(2) *Tension* is the force pulling at opposite ends of a structural part. Movement of the controls by the pilot causes tension on the control cables.

(3) *Bending* is the force applied to a structural unit, or beam, at other than the supporting points. It is a combination of compression and tension. When bent, one side of the beam is pushed together and the other side is stretched.

(4) *Torsion* is the force which tends to twist a structural unit. Torsion is exerted on the propeller shaft by the engine turning the shaft and the propeller resisting the turning force.

(5) *Shear* is the force which tends to cut an object in two by a sliding action. Two pieces of metal, fastened together by rivets, subject the rivets to shearing action when force is applied to the pieces of metal and they tend to slide across each other.

b. Stresses seldom act singly, but in combinations of two or more types. All five stresses may be acting on an aircraft at the same time, although any one point cannot have more than four stresses acting on it simultaneously since tension and compression cannot act on the same point at the same time.

When stresses effectively act on a structural member, the result is called *strain.*

31. Dynamic Loads

In addition to the stress placed upon an aircraft by normal flight, it must be designed to withstand stresses caused by acceleration and resulting centrifugal force. These additional stresses are called *dynamic loads* and are measured in terms of load factors (G unit). They may be caused by various maneuvers, such as loops, snap rolls, steep turns, and abrupt pullouts from dives. Such maneuvers if improperly done may cause a dynamic load greater than the structure of the airplane can withstand, causing structural failure.

32. Structural Units

The principal structural units of an aircraft are the fuselage, wings, control surfaces, powerplant, and landing gear. Each has a specific function and when considered collectively are called *airframe* or *aircraft structure.*

a. The *fuselage* is the main body of an aircraft to which the other structural units are fastened. It will contain the crew and cargo, except external loads, and on single engine aircraft will usually contain the powerplant. There are two main types of construction used for the fuselage, *truss* and *monocoque.*

(1) The truss type is now mostly used on fabric-covered aircraft. Most common is the Warren-type truss, which consists of an all-welded frame, the members being arranged in the form of triangles. Its main advantage is that members are subjected only to tension or compression stresses. However, a more suitable type construction for military use is the semimonocoque, a modified monocoque.

(2) A true monocoque construction consists of the shell only, with no internal bracing to help carry stresses. Consequently, it requires heavy metal for the shell and is not too desirable for military aircraft. The semimonocoque construction utilizes rings, bulkheads, and stringers inside the shell to help give shape and carry stress. The shell, or *stressed skin,* is fastened to the internal members and can be of lightweight metal. Since stresses are divided between skin and internal bracing, vital or critical points are for the most part eliminated.

b. The *wing* provides the lifting force that makes an aircraft fly and supports the weight of the aircraft during flight. Its design is dependent on such factors as size, weight, and purpose of the airplane, as well as desired speed for flight and takeoff. There are two general types of wing construction: internally and externally braced wings, which are called *cantilever and semicantilever,* respectively. Each type may be covered with cloth or stressed-skin. Cloth-covered wings are light in weight and quite suitable for small slow-speed airplanes which usually are not subjected to severe stresses. Stressed-skin wings distribute the load over more of the wing area and thereby can carry more load or stress without failing. Most military airplanes are constructed with stressed-skin wings.

c. Control surfaces are supplementary airfoil sections which the pilot uses to control the flight of the airplane. Primary control surfaces are the ailerons, elevators, and rudder; they are constructed on the same principle as an airfoil and are covered with cloth or metal. The *ailerons* are attached by hinges to the outer panels of the trailing edge of the wings. Secondary control surfaces are trim tabs, balance tabs, and servo tabs; these are attached to the primary control surfaces and may be used to balance the airplane in flight or reduce the force required to move primary control surfaces. The elevators and rudder are part of the *empennage,* which is the entire tail group. In addition to elevators and rudder, the empennage contains the *stabilizers.* These are normally fixed surfaces, one vertical and one horizontal. The vertical stabilizer is used to help maintain directional stability. Attached to it by a hinge at the trailing edge is the *rudder.* The horizontal stabilizer may or may not be fixed. It helps to maintain longitudinal stability and, if movable, it used for trimming the aircraft longitudinally. Attached by a hinge to the trailing edge of the horizontal stabilizer are the *elevators.*

d. The *powerplant* consists of engine, propeller, and necessary accessories for operation of the engine. On single-engine airplanes the powerplant normally is mounted in the front of the fuselage. On multiengine aircraft, powerplants usually are mounted in nacelles on the wings. Most modern aircraft use air-cooled engines with either *radial* or *opposed* cylinders; some still use liquid-cooled engines, which usually have *in-line* cylinders.

e. The *landing gear* consists of wheels, shock absorbers, and possibly a retracting mechanism. Most small airplanes have fixed gear; however, larger, faster airplanes usually have retractable landing gear, which cuts down on overall drag and stress while in flight.

33. High Lift Devices

Only one angle of attack for a given speed will maintain a constant altitude. Flying too slowly results in excessive angle of attack and eventual stalling. The minimum or stalling speed for the average aircraft is about ⅓ or ⅖ of the maximum level flight speed. High landing speeds are disadvantageous in airplanes because of the natural dangers of fast landings and because large emergency airports are scarce. For these reasons, the modern airplane is equipped with devices to reduce the landing speed.

a. Controlling Speed. Assume that an airplane is normally landed at the minimum flying speed for a given load. The minimum speed for flight can be found by use of the lift formula:

$$L = C_L \times \frac{D}{2} \times A \times V^2$$

To maintain horizontal flight, lift must equal weight, and the formula may be restated:

$$W = C_L \times \frac{D}{2} \times A \times V^2$$

To find the minimum speed possible, the formula may be further altered:

$$V^2 \text{ minimum} = \frac{W}{C_L \text{ maximum} \times \frac{D}{2} \times A}$$

or

$$V \text{ minimum} = \sqrt{\frac{W}{C_L \text{ maximum} \times \frac{D}{2} \times A}}$$

(1) The only factors that can be controlled in lowering the minimum speed are the coefficient of lift (C_L) and the area of the wing (A). Density of the air cannot be controlled, and it is not practical to decrease weight by dumping crew, cargo, or equipment before landing.

(2) Variations in wing area, while aerodynamically sound, entail structural difficulties. The rigidity of the wing must not be impaired; the necessary additional weight of the operating mechanism must not be excessive; the strength of the wing must be maintained; and shape of the section cannot be detrimentally affected by the variation.

(3) The factor most commonly changed is coefficient of lift. It may be altered by changing the airfoil or camber while in flight. The greatest effectiveness would result through increase of the upper camber of the entire wing, but this operation has more structural objections than variation of the area. There remains, then, the variation of camber by turning down the trailing edge of the wing.

b. Flaps. The portion of the wing that can be turned down is called the *flap,* which improves the lift of the wing by increasing the camber. It also acts as an airbrake since it creates more drag. In doing so, it affords steep descents without an increase in airspeed. Flaps have the advantages of lowering the landing speed and controlling the angle of descent.

34. Types of Flaps

There are three common types of airplane flaps in use today. They are the *simple flap,* the *split flap,* and the *Fowler flap.* Though they differ in operation, their design and construction generally parallel that of the airfoil.

a. The simple flap is a movable continuation of the trailing edge of the wing. It is similar to the aileron, except that it moves downward at the same time and angle as its companion flap on the other wing. When lowered, the simple flap increases camber of the wing and thus increases airfoil lift for a given angle of attack. However, the simple flap not only increases lift but also increases drag. This increase of drag permits a steeper glide without a corresponding increase in gliding speed.

b. The split flap consists of a flat, movable section beneath the trailing edge of the wing. When in use, it is lowered in the same manner as the simple flap, but the upper surface of the trailing edge remains in a fixed position. Its main purpose is to create drag.

c. The Fowler flap not only increases the effective angle of attack by increasing the camber but also increases the wing area. The flap moves both down and backwards, sliding out from its mounting beneath the trailing edge. Usually it is designed to form a small slot between the trailing edge of the wing and the leading edge of the flap (extended) to help decrease burbling at high angles of attack.

35. Use of Flaps

When flaps are lowered, the airplane reacts in a pronounced manner, and the pilot must adjust his controls to the changes. When using flaps, a safe margin of speed above stalling must be maintained by keeping the airplane nose down.

a. Flaps should never be lowered at excessive speeds, for great stresses are produced by the sudden change in the effective angle of attack. When flaps are lowered, they convert speed into lift and create more drag.

b. Flaps should never be retracted suddenly at low airspeeds, as this causes a sudden loss of lift which will let the airplane sink. It is especially dangerous when near the ground.

36. Types of Slot Arrangements

There are two types of slot arrangements. One type is fixed, and is built into the wing, a few inches back of the leading edge. The other type slot arrangement is commonly known as a *slat.* It is designed into the leading edge of the wing and in normal flight is a part of the wing. As airspeed decreases, it may be extended from the wing to form the slot, either manually or automatically.

37. Effect of Slots

Burble is caused by eddies of air over the top surface of the wing. If the eddies can be reduced, the burble point will not occur until a higher angle of attack is reached. To reduce these eddies, some wings have a slot near the leading edge of the wing. At high angles of attack, the air passes through the slot and smooths airflow over the wing, which delays the stall. Slots are commonly installed near the outer end of the wing in front of the ailerons, so as to make the ailerons more effective near the burble point when they are most needed. Two of the greatest advantages of slots are reduced stalling airspeed and prolonged aileron control during a stall.

Section II. STABILITY

38. Types of Stability

All airplanes possess some type of stability for safety and ease of operation. Design and construction of the airplane primarily determine its stability. There are three general types of stability an airplane may possess—*positive, neutral,* or *negative.*

a. Positive stability, often referred to as stability, is the type which causes the airplane to return to its original attitude when disturbed by an outside force. It may further be divided into static and dynamic stability.

(1) Static stability tends to return an airplane to its original position when its course is disturbed.

(2) Dynamic stability is concerned with the oscillation an airplane goes through in returning to its original position. If the oscillation steadily decreases in amplitude, the airplane is dynamically stable; but if the oscillation steadily increases in amplitude, the airplane is dynamically unstable.

b. Neutral stability causes an airplane to maintain its attitude in flight. However, if the attitude is changed by an outside force, the airplane will tend to maintain the new attitude until again disturbed by an outside force.

c. Negative stability, often referred to as instability, tends to change an airplane from normal to abnormal flight. It constantly works against the pilot.

39. Stability About the Axes

Airplane stability is accomplished by controlling movement about its three axes. There are certain features incorporated in the design of an airplane which give stability about its longitudinal, lateral, and vertical axes.

a. Longitudinal stability makes an airplane stable about its lateral axis. Without this stability the airplane tends to climb or dive until stalled or until it falls apart from excessive airspeed. Longitudinal stability is achieved by placing the center of gravity ahead of the center of pressure. This alone would cause the airplane to dive continuously. However, the horizontal stabilizer is designed for a negative angle of attack and negative lift which counterbalances the nose-heaviness. Air passing over the wing is deflected downward, causing the relative wind of the horizontal stabilizer to produce a negative angle of attack and negative lift. If airspeed decreases, negative lift is less and the nose of the airplane will lower, causing an increase in airspeed. As airspeed increases, the negative lift increases also, causing the nose to rise. If the center of gravity is moved too much by improper loading, this stability may be adversely affected and lost.

b. Lateral stability makes an airplane stable about its longitudinal axis. It prevents the airplane from constant rolling. Lateral stability is most commonly achieved by *dihedral* (designing the wing tips higher than the wing roots). As one wing drops, the dihedral causes the lowered wing to have more lift than the raised wing. The differential of lift between the two wings tends to right the airplane. Lateral stability is also achieved by *keel effect*. The fuselage of the airplane reacts to air like a keel of a ship to water. By placing the center of gravity low in the fuselage, any rolling tendency is dampened by the weight pulling downward.

c. Directional stability makes an airplane stable about its vertical axis. It tends to prevent an airplane from yawing (turning). Sweepback of the wings (the leading edge tapers back until the tip is to the rear of the root) provides some directional stability. The vertical stabilizer also provides directional stability, as does the fuselage action in the slipstream. Both surfaces tend to weathervane, or turn the airplane into the relative wind.

PART TWO

PRIMARY FLIGHT MANEUVERS

CHAPTER 7

TAXIING

40. General

Flight of an Army airplane is normally preceded and followed by taxiing. Although taxiing is basic and comparatively simple, taxi accidents are common. There is little if any excuse for them.

41. Use of Throttle and Flight Controls

a. Taxiing is the controlled movement of an airplane across the ground under its own power, except that movement incident to takeoff and landing. The taxi speed is normally that of a brisk walk; however, the existing taxi area and other conditions may alter it. Throttle, assisted sparingly and only when necessary by brakes, is used to attain and maintain desired taxi speed. The steerable tail or nose wheel, and rudder, ailerons, and brakes are used for directional control.

b. The amount of throttle required to start the initial roll is considerably greater than that for normal taxiing speed. Throttle should be applied slowly and, as soon as the aircraft starts to move, the brakes should be tested for proper functioning. After the taxi roll is underway, a constant power setting is desirable; however, if turns are made, throttle adjustments for varying wind effects may be required to maintain proper taxi speed. S-turning normally is required to provide better pilot visibility. This precautionary practice often prevents an accident. When working in confined areas, however, the S-turn may be impossible, and reduced speed may be the only precaution possible.

c. Wind has a definite effect on the airplane while on the ground. It tends to retard or increase speed, as well as turn the airplane. A light airplane taxiing crosswind can be upset if the pilot makes improper use of controls.

(1) If taxiing into a direct headwind (fig. 17), the stick should be held straight back in order to raise the elevators and exert downward force on the tail to hold it on the ground. If the wind is quartering off the

Figure 17. Stick position for taxiing, headwind.

nose, the stick is positioned so as to utilize the elevators and ailerons effectively to help keep the airplane upright. To do this, the stick is held back and toward the windward wing (fig. 18). In this position, the aileron on the windward wing moves up, spoiling lift, while simultaneously the

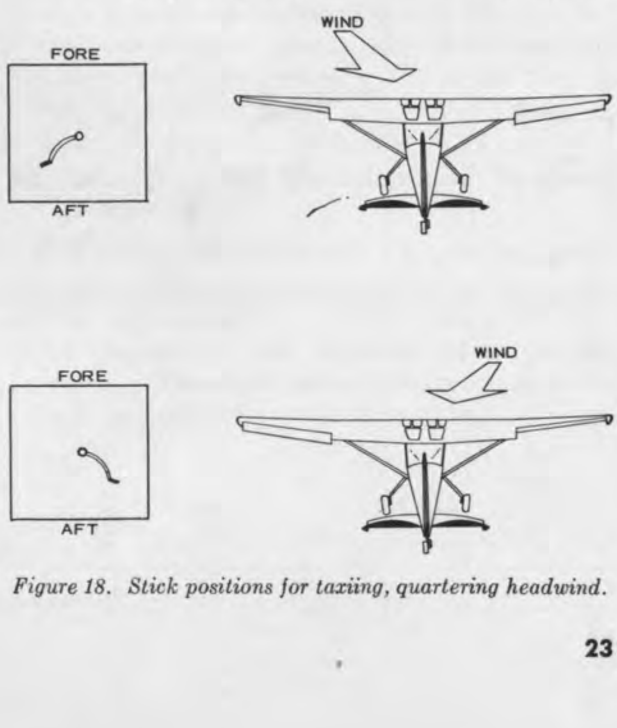


Figure 18. Stick positions for taxiing, quartering headwind.

aileron on the leeward wing lowers and creates more lift on that wing. This also creates more drag and helps counteract weathervaning tendencies. The elevator is raised to hold the tail down. In essence, then, the proper stick position for any headwind while taxiing is back and toward the windward wing.

(2) With a tailwind, the stick normally is moved forward (fig. 19) to lower the elevators, allowing the wind to move up and over the elevators and exert downward force on the tail. If the wind is quartering off the tail, the stick is held forward and downwind (toward the leeward wing) (fig. 20). In this position, the elevators produce downward force and the leeward wing aileron produces an upward force. The downward-deflected aileron also helps prevent weathervaning tendencies.

(3) Elevator position should never be held with force while taxiing in a tailwind. The propeller slipstream or taxi speed may be strong enough to offset the tailwind; if so, the elevator has to be moved up to hold the tail down. Slight downward position of the elevator is then normally desirable to allow for wind gusts when this condition exists. Less throttle is required to taxi with a tailwind because the wind helps to move the airplane. Brakes are used as necessary to prevent excessive speed.

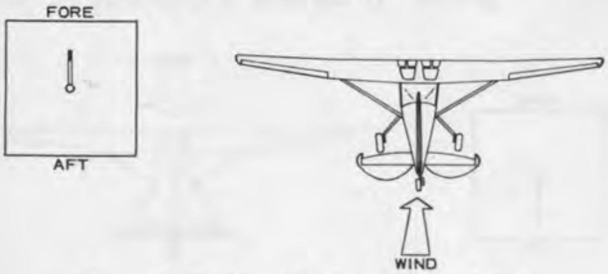


Figure 19. Stick position for taxiing, tailwind.

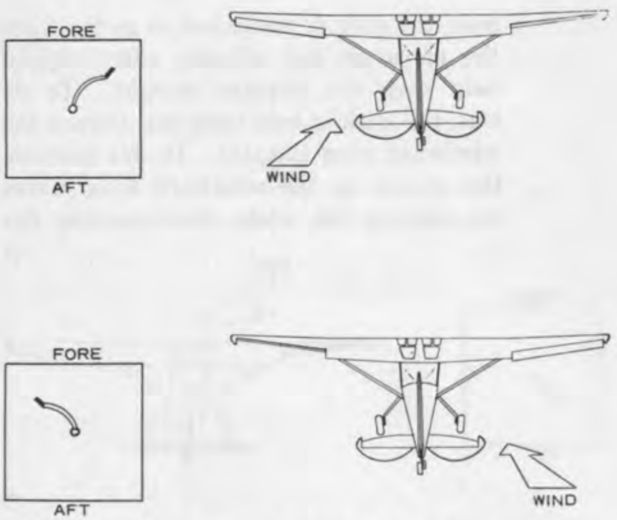


Figure 20. Stick positions for taxiing, quartering tailwind

42. Taxiing Precautions

Most taxiing accidents can be eliminated by observing a few rules:

a. The aircraft must be kept under constant control.

b. S-turns should be used when possible, to afford maximum visibility of the taxi area.

c. Speed must be commensurate with the taxi area and pilot proficiency.

d. Sharp turns are not to be attempted at excessive speeds.

e. In confined areas, wingmen or ground signalmen should be used.

f. At night, extra precautions must be taken.

g. A thorough ground reconnaissance should be made prior to taxiing the airplane when in doubt about the area.

h. If the area appears to be too small, the airplane should be moved by hand.

i. Controls are positioned according to wind direction and speed.

j. Wing-walkers are used when wind speed is excessive or directional control likely to be too difficult or dangerous.

CHAPTER 8

TAKEOFFS

43. General

Actual flight begins with the takeoff. As the throttle is advanced to start the roll down the active runway, the takeoff begins; it continues until the airplane becomes positively airborne. Mastery of the takeoff is a basic requirement of flying.

44. Normal Takeoff

The normal takeoff (fig. 21) is made directly into wind, or as direct as the runway will allow. In this manner, the airplane becomes airborne with less ground roll and speed.

a. After clearance for takeoff is received from the tower, the airplane is moved onto the active runway and alined down its center. The tail wheel is straightened and the throttle advanced, slowly and smoothly, in one continuous motion, until maximum permissible power in reached—some stick back pressure should be maintained during initial roll. Since engine torque and propeller wash tend to turn the aircraft, the rudder is used to counteract this tendency. If throttle application is too rapid or uneven, it may not be possible to maintain directional control with the rudder alone. In this case, brakes may be used to aid the rudder action. If directional control cannot be maintained, power should be reduced and the takeoff attempt ended. A successful second attempt is better than a ground loop on the first.

b. Once the roll is started, caution is used to prevent inadvertent application of the brakes. They are used only as a last resort to maintain directional control. As the roll progresses, the tail may be raised by slight forward stick pressure or it may be allowed to raise itself as speed increases. As takeoff speed approaches, slight back pressure on the stick is applied to prevent the tail from rising any higher. The airplane thus should break ground in an attitude slightly tail-low as compared to the attitude of level flight. As the airplane leaves the ground (fig. 21) and starts a shallow climb, it should be allowed to build up airspeed to normal climb, and then normal climb attitude is assumed. Once off the ground, power can be reduced to normal climb. The climbout should be straight from the runway.

c. Flaps are sometimes used for takeoff. They provide a quicker takeoff at slower airspeed. After a safe altitude is reached, flaps should be retracted.

45. Effect of Wind

Takeoff is dependent upon deriving sufficient lift from the wings to overcome the weight of the airplane. By taking off into the wind, the airplane has an airspeed equal to the headwind component before the takeoff is started. Therefore, less ground speed is required to become airborne (A, fig. 22). A downwind takeoff requires considerably more runway (B, fig. 22) since ground speed is increased above the takeoff airspeed in proportion to the value of the tailwind. An airplane which will become airborne at 60-mph airspeed, taking off into a 20-mph wind, will have a ground speed of only 40 mph. But if the same airplane were to take off downwind in the same wind, the ground speed at the time of takeoff would be 80 mph.

46. Effect of Field Elevation and Temperature

As altitude and temperature increase, air density decreases. This causes a corresponding decrease in lift for a given airspeed. Performance of the propeller and engine also decreases as air density decreases. Therefore, more time is required for takeoff airspeed to be attained, resulting in a longer

Figure 21. Normal takeoff.

ground roll and a requirement for a longer runway. The increase in runway length requirement increases approximately 20 percent per 1,000 feet increase in altitude (fig. 23).

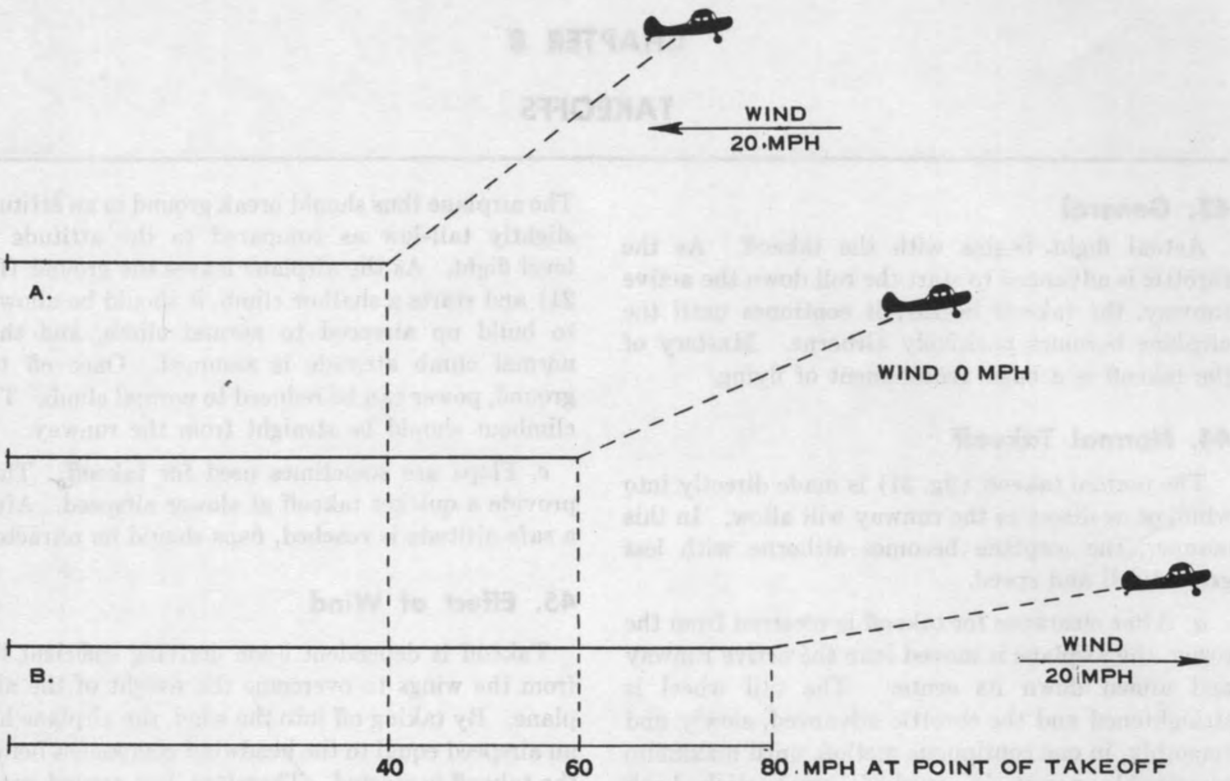


Figure 22. Effect of wind on takeoff.

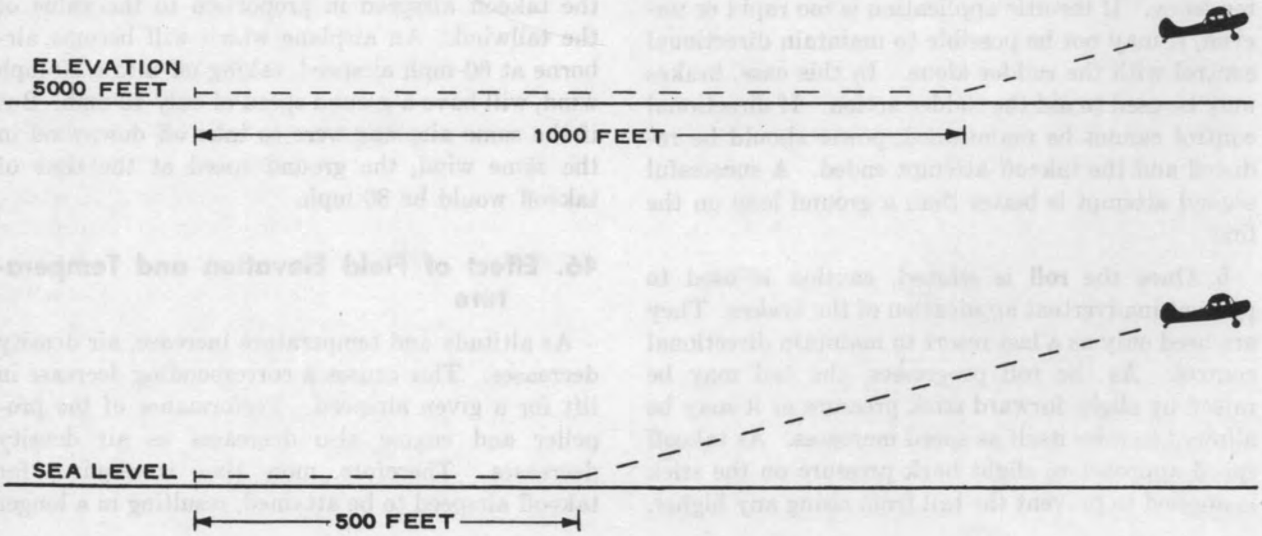


Figure 23. Effect of altitude on takeoff.

CHAPTER 9

FUNDAMENTALS OF FLIGHT

47. General

There are four fundamental flight maneuvers: straight and level, climbs, glides, and turns. Mastery of these four fundamental maneuvers is one of the prime requisites for pilot proficiency since all other flight is a combination of two or more of these.

48. Straight and Level

a. Perhaps the most difficult maneuver is straight and level flight since heading and altitude have to remain constant with the wings level. This is impossible to maintain for any extended length of time because so many factors affect an aircraft's flight attitude. Many small corrections are required for straight and level flight.

b. The airplane must be kept steady with relationship to the horizon and its own three axes. Until experience is obtained, points on the aircraft are used for each airplane axis.

c. The longitudinal or pitch reference point for level flight is usually some portion of the nose, cowling, or even a bolt on the windshield. This reference point may not rest directly in line with the horizon in level flight but it will serve that purpose if the variation from the horizon is clearly established in the pilot's mind. A relative increase of distance between the eye and the reference point permits easier and quicker notice of changed relationship between the point and the horizon. When this reference point falls below the desired relationship, back pressure on the stick may be required for return to straight and level flight; or, if this point rises above the established relationship, forward stick pressure is required. With variations of airspeed, the reference point or the relationship will have to be changed to fit the new level-flight attitude.

d. The lateral (roll) reference point is usually determined by an equidistant comparison of the wing tips to the horizon. This is controlled by the ailerons.

e. Checking the lateral axis for straight and level flight serves the additional purpose of verifying clearance of the area. This is an important safety habit for the pilot. Furthermore, the head motion eases pilot tension and lessens fixity of attention to a limited field of vision.

Note. Natural weight of the relaxed arm tends to hold the stick to the right of neutral, lowering the right wing. This tendency must be guarded against. It results in decreased airplane efficiency and discomfort of passengers because the airplane is leaning (slipping).

f. Straight flight is best achieved by establishing flight relationship with a section line, fence line, road, or any other ground reference point and the nose (longitudinal axis) of the airplane. Normally the rudder is used to make minor corrections and maintain straight flight.

Note. A change to one of the three axes affects the others. Therefore, additional control pressures are required for the other axes. Small uncorrected mistakes soon become large. Hence, any deviation from straight and level flight should be corrected promptly when recognized. In attempting to maintain straight and level flight, however, the aviator must not constantly alter flight controls. An airplane will roll and pitch with air turbulence, but it should be allowed to level itself by inherent design stability if practicable. Extreme pilot fatigue results if the pilot attempts constant control corrections.

49. Climbs

Climbs are used for ascent from one altitude to a higher altitude. There are two different climbs that an Army aviator will use: the *best rate of climb*, hereafter referred to as *normal climb;* and the *maximum angle of climb*, which is used only for short duration as the requirement exists. Maximum climb is discussed in paragraph 92.

a. The *normal climb* is made at an angle and airspeed which will give the best lift-drag ratio at climb power setting. Airspeed for the normal climb is less than cruise but well above stalling, and power setting is above normal cruise setting but usually less than full throttle.

b. Normal climb attitude is entered from straight and level flight by back pressure on the stick. As the nose starts to rise, airspeed begins to dissipate, and power should be added, slowly and smoothly, to obtain climbing power and speed simultaneously.

Climb attitude is maintained by reference points on the airplane related to the horizon until flight experience is developed.

Note. Flight controls *feel* quite different to the pilot at the slower climbing airspeed, and they react to pilot pressures more slowly. In addition, airflow about the cockpit decreases in sound intensity, while engine noise increases due to increased power and aerodynamic loading.

c. Torque effect increases during the climb. To compensate for it, an increase of pressure on the right rudder pedal is required throughout the climb. If rudder trim is available by cockpit control, it should be used to relieve pedal pressure. Elevator trim, if available, should also be used to relieve stick pressure during the climb.

d. When the desired altitude is reached, the airplane is returned to level flight at normal cruise power and airspeed. This is best accomplished by starting to lower the nose of the airplane as the desired altitude is approached, usually about fifty feet prior, and, maintaining climb power. The level-off is timed so that altitude and cruising airspeed are reached simultaneously, followed by power reduction to normal cruise. The airplane is then retrimmed for straight and level flight at normal cruise.

(1) As airspeed increases during the level-off, less pressure on the right rudder pedal is required. This pressure should be evenly reduced to maintain straight flight.

(2) Power should be reduced and the airplane retrimmed only after straight and level flight at normal cruise airspeed is attained. Any attempt to reduce power and trim before attaining cruise airspeed my result in too little airspeed for normal cruise power.

50. Glides

The glide is used to descend from one altitude to a lower altitude. The *normal glide* is a glide at an angle and airspeed permitting the greatest forward distance with a given loss of altitude.

a. To enter the glide from a straight and level flight, the throttle is closed in a smooth, slow motion. Airplane attitude remains constant until the airspeed dissipates to normal glide airspeed for the particular airplane, at which time the nose is lowered to maintain that airspeed. With reduced power and airspeed, control pressures are changed on both stick and rudder pedals to maintain glide attitude. Without power, the airplane tends to turn to the right, and left rudder pedal has to be used to counteract this tendency. As airspeed decreases, additional back pressure must be applied to the stick to keep the nose in proper glide attitude. When gliding airspeed is reached, back pressure is reduced to let the nose lower and maintain gliding airspeed. Subsequent control pressures are applied only as necessary to maintain the gliding attitude. If trim is available, it is used to relieve pilot control pressures.

b. As in the climb, initial glide training requires reference points to maintain correct glide attitude until the ability to sense and feel the proper speed and attitude are developed. The marked absence of engine noise permits keener perception of changes in airspeed and helps in making corrections.

c. The level-off from a normal glide should begin about 50 feet prior to reaching the desired altitude. At this time, power is added, slowly and smoothly. Airspeed starts to increase and, with proper timing, simultaneously reaches normal cruise with normal cruise power and straight and level flight. As power increases, less pressure is required on the left rudder pedal. After the airplane has stabilized in straight and level flight attitude, it is retrimmed to relieve pilot control pressures.

d. Wind affects a glide (fig. 24) as it affects any other type of flight in relation to ground track and distance covered. In a headwind, the glide path will be steeper, if the airspeed remains unchanged, because the effective headwind will reduce the ground speed of the airplane by the amount of that component. An airplane gliding at 60 mph into a headwind of 60 mph will have a ground speed of approximately zero and as a result will make an almost vertical descent. By the same analysis, the same aircraft gliding with a 60 mph tailwind will have a ground speed of approximately 120 mph and

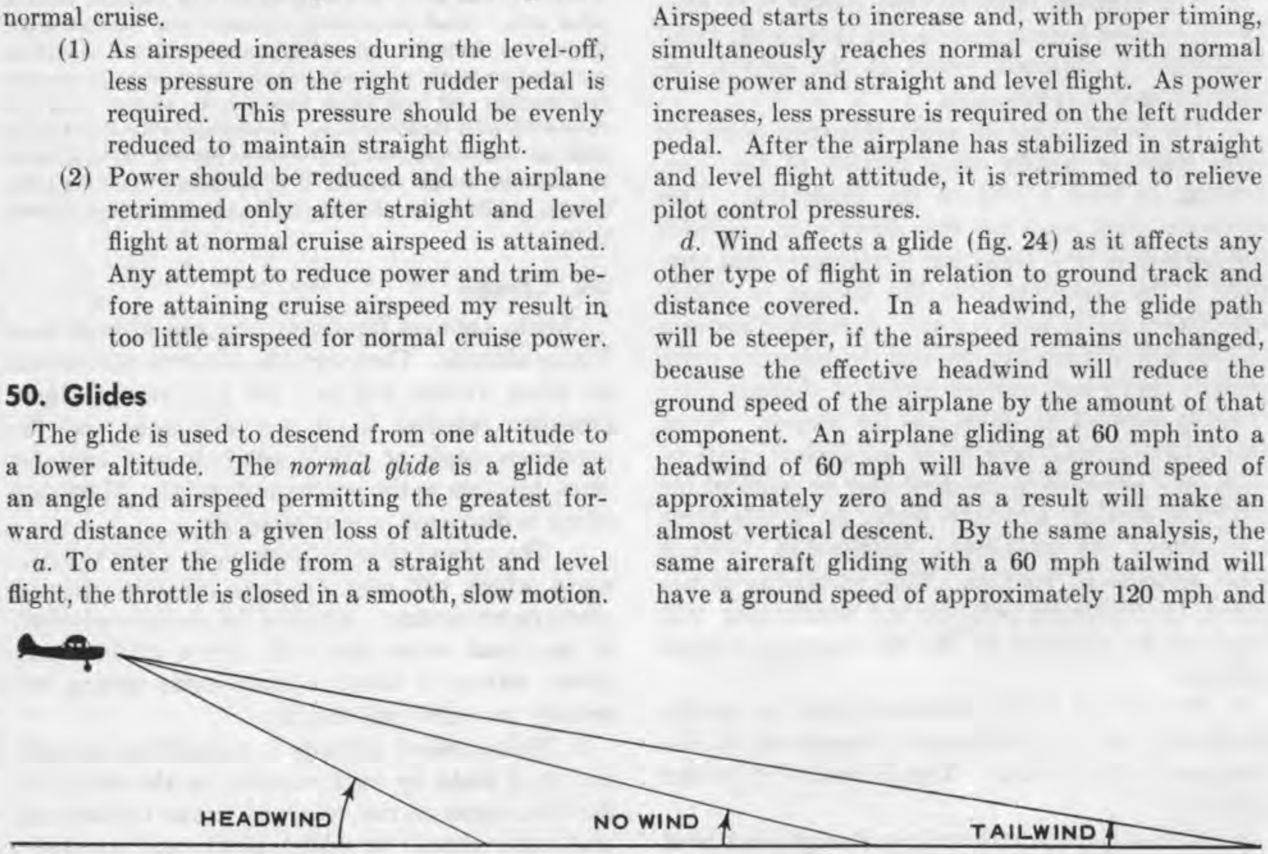


Figure 24. Effect of wind on a glide.

a proportionately shallower glide path. The effect of wind on a glide is dependent on the time spent flying in it. A faster glide in a headwind may result in greater ground coverage. However, a slower glide with a tailwind will not increase the ground coverage since it will cause a faster rate of descent; this results in less time being spent in the wind.

51. Turns

Turns are used to change the direction of the flight path. There are three general types of turns: *gentle, medium,* and *steep.*

a. Turns are made by changing the direction of lift from vertical toward the horizontal. To change the direction of lift, the wings are banked by means of the ailerons. The differential of lift on the primary airfoils produced by the aileron movement causes the airplane to bank.

b. Movement of the ailerons also causes yaw in the opposite direction of the desired turn. But while the aircraft is yawing, the differential of lift is also taking effect and eventually overcomes yaw, turning the airplane in the desired direction. Slight stick pressures reduce the yawing tendency but considerably increases the time to establish the bank.

c. Since turns may have to be entered rapidly, rudder is used to control yawing. Rudder is not, however, used to turn the airplane. As the stick is moved to the left, left rudder is required for counteracting yaw until the bank is established. Rudder is then eased off to streamline with the turn (A, fig. 25). If the aviator holds heavy rudder pressure, the airplane will skid (B, fig. 25). If, on the other hand, the rudder is neutralized, the airplane will slip during the turn (C, fig. 25).

d. An airplane is correctly banked, and subsequently turned, only by coordinated use of rudder and ailerons. The relative use of these two controls is determined by the characteristics of the particular airplane and the airspeed at which the maneuver is executed. After the airplane has been banked for a turn, the angle of bank should be held constant without skidding or slipping. This requires some adjustment of both ailerons and rudder pressure, depending upon the characteristics of the airplane and its speed. No general rules can be set for determining, in advance, the exact amount of rudder and aileron pressure to be used in turning any specified airplane; the pressures must be learned from actual experience.

e. When a turn is started, increase of stick back pressure is required to maintain a level turn. This increases the angle of attack and results in more lift, which compensates for the bank and for the centrifugal force of the turn. The amount of back pressure on the stick is coordinated with the steepness of the bank.

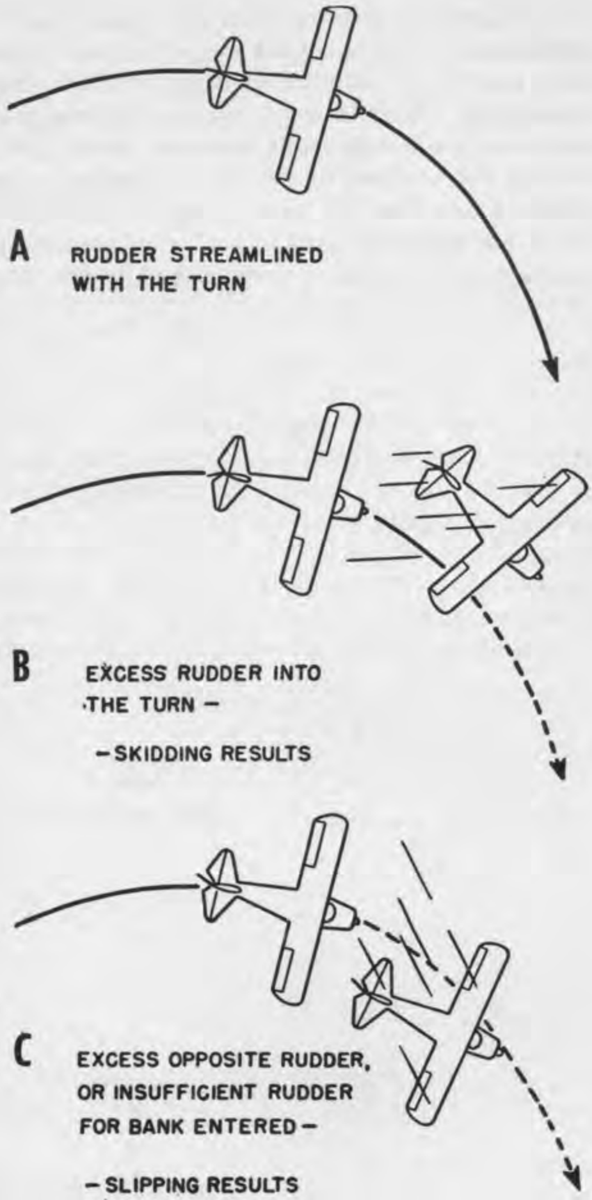


Figure 25. Effect of rudder in turns.

f. The stalling speed of an airplane is increased in a turn due to the increase of aerodynamic load caused by centrifugal force. The increase of stalling speed is proportionate to the square root of the load factor. Therefore, an airplane with a normal stalling speed of 60 mph will stall at 120 mph with a load factor of *4 G's* (par. 23*b*).

g. Climbing turns are generally made using a gentle bank. With this bank angle, the bank is not steep enough to cause the resultant of lift to drop appreciably. Since, however, airspeed is lower than normal cruise and power is increased, torque tends to turn the airplane to the left. Entry of a left climbing turn does not always require left rudder pedal, but instead a slight relaxation of pressure on the right rudder pedal to prevent the airplane from skidding. Entering a right climbing turn, rudder pressure must be increased more to overcome torque than in a straight climb.

h. Gliding turns should generally be at a medium bank. However, if the situation requires a steeper bank, the aviator must remember that stalling speed increases as the bank increases, and that the reduced speed of the glide leads to an earlier stall with less bank than at normal cruising speed.

CHAPTER 10

CONFIDENCE MANEUVERS

52. General

Most airplanes must be forced into a dangerous attitude and, even then, if permitted to do so, they will usually right themselves to normal flight attitude. Through the practice of confidence maneuvers, respect and admiration for airplane stability and maneuverability is gained.

53. Slow Flight

a. Slow flight serves two purposes. It teaches the beginning student that the airplane will fly with sufficient control at reduced airspeeds. For the experienced aviator, it serves as a review and coordination exercise for power approach technique (ch. 20). Slow flight may be at any airspeed between normal cruise and stalling but is usually flown about 10 mph above stalling airspeed. Power is used as necessary to control altitude.

b. Slow flight is entered by reducing power and letting the airspeed dissipate. Altitude is kept constant by increasing stick back pressure as airspeed dissipates. When the desired airspeed is reached, required power is added to control altitude. Turns can then be executed, but the angle of bank should be very limited due to reduced airspeed.

54. Stalls

a. An airplane will stall only when an excessive angle of attack is reached. The stall (fig. 26) may occur at reduced airspeed or at an airspeed above normal cruise following an abrupt change of attitude. When the stall occurs, the aviator must be able to recognize it as such and take proper corrective action. Practice stalls are, therefore, part of confidence maneuvers.

b. An airplane will stall at the same angle of attack whether with power on or power off. The pitch attitude, however, is considerably different. In a power-off stall (A, fig. 26) the throttle is closed and a normal glide is entered. The nose is raised approximately to the three-point attitude and this attitude is maintained until the stall occurs. At this time, the nose will drop below level flight attitude, and, as flying speed is regained, the airplane will tend to assume a normal glide attitude. If improperly rigged or if the wings are not level as the stall occurs, the airplane may fall off on one wing; that is, instead of the nose falling straight through, it will start turning toward one wing. As flying speed is regained, however, the airplane may tend to correct its attitude.

c. For the normal power-on stall (B, fig. 26), power and resultant thrust require greater pitch attitude. Normally a given pitch attitude is maintained until the stall occurs. As airspeed starts dissipating, torque begins to take effect and is com-

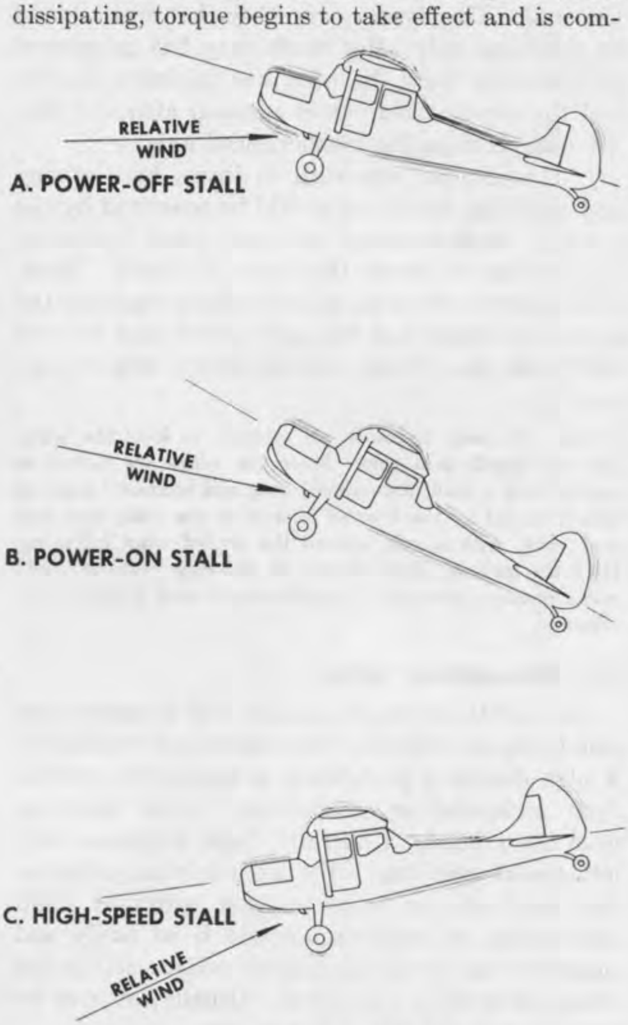


Figure 26. Relative stall attitudes.

pensated with right rudder. As stall occurs and nose starts dropping, with airspeed increasing, right rudder pressure is released to prevent the airplane from turning.

d. Initially, stall recovery should be effected in a positive manner, by lowering the nose and applying full power to regain flying speed, then easing back on the stick and reducing throttle to attain straight and level flight at cruising power. A constant heading is maintained throughout the recovery. To reduce the angle of attack to an angle less than the stalling angle, which varies with the type of airplane, the pilot either lowers the nose, adds power, or both.

e. As proficiency in stall recognition and recovery develops, the pilot can complete the recovery with less loss of altitude. This should be practiced until recovery can be made immediately as the stall occurs. Application of full throttle as the airplane stalls increases the thrust, and thereby helps break the stall. This type of recovery, however, should be practiced only after proficiency has progressed satisfactorily since the pilot has minimum control and the airplane may enter unusual attitudes that are dangerous to the inexperienced aviator.

f. The airplane can stall in turns, both gliding and climbing, and these should be practiced by the aviator. Stall recovery is accomplished by lowering the nose to lessen the angle of attack. Then, after appreciable flying speed has been regained, the wings are leveled and the nose pulled back to level flight attitude. Power may be used to help execute recovery.

Note. In some airplanes, an attempt to level the wings first can result in a spin. Since the wings are stalled or approaching a stall, the induced drag and increased angle of attack caused by the lowered aileron on one wing may stall that wing, with a spin toward the stalled wing following. Near the ground, little chance of recovery from this spin exists because the spin is unintentional and surprises the aviator.

55. Elementary Spins

The ability to recover from a spin is essential to safe flying and bolsters pilot morale and confidence. A high degree of proficiency is required to recover from accidental or unintentional spins occurring near the ground. Generally, light airplanes defy intentional spinning. Yet at minimum airspeed they may enter an accidental spin with only slight mishandling of controls, and do it so easily and smoothly that the inexperienced aviator detects the change only after spin entry. Usually, little or no warning precedes this type of spin.

a. The normal intentional spin is a maneuver in which the airplane descends in a helical path while in a stalled condition, rotating about its vertical and longitudinal axes. It may be entered from either a power-on or power-off stall.

b. When the spin is entered, proper pilot control to keep the airplane spinning consists of full rudder, full back stick, and neutral ailerons. Rudder is held toward the inside of the spin. Ailerons should not be used in a spin because their use aggravates the stalled condition. If either rudder or elevator pressure is relaxed, the airplane normally tends to fly out of the spin.

c. Recovery from the spin is achieved by stopping the rotation and breaking the stall. Rotation is stopped by applying positive, opposite rudder. In most airplanes, the stall is broken by releasing back pressure, at which time the rudder is neutralized to avoid a skidding recovery. The airplane is then eased out of the resulting dive by slight back pressure on the stick, and returned to straight and level flight. Power is added as airspeed returns to normal cruise. If the recovery from the dive is too abrupt, a secondary stall may occur, with recovery from it resulting in a further increase of airspeed. It is also possible to exceed maximum safe load limit if the pull-out from the spin is too fast.

56. Elementary Forced Landing

a. A forced landing may be caused by a partial loss of power or complete engine failure, malfunction of one or more controls, collision with an object, expiration of fuel supply, bad weather, disorientation, and so forth. By being constantly alert for such conditions, an aviator will be better able to meet the requirements presented by a forced landing. Through practice of simulated forced landings, he learns to react to the situation quickly and confidently.

b. Forced landings require considerable proficiency in glides since they are usually performed with little or no power. Each forced landing, simulated or actual, has specific problems that may never again be duplicated; therefore, each requires thorough planning. The aviator must plan his landing pattern while retaining control of the airplane and follow the selected plan thereafter except to avoid certain disaster.

c. After power is reduced for a simulated forced landing, the airplane is glided from the initial altitude until the pilot can determine that the maneuver would or would not be successful. During the glide, he performs the cockpit procedure necessary to accomplish an air-start while selecting the landing area and planning the approach. Turns onto final approach should be made at a safe altitude. After determining the success of the simulated maneuver, power is added and the airplane climbed back to altitude.

CHAPTER 11

COORDINATION EXERCISES

57. General

Coordination exercises vary in degree of difficulty, but together develop and maintain proficiency in the coordinated use of flight controls. They should be practiced throughout an aviator's career.

58. Banks Without Turns

a. The first of two elementary coordination exercises is that of a series of banks without letting the airplane turn, sometimes referred to as the "Dutch Roll" or control timing. Although the airplane does not always maintain coordinated flight during the maneuver, the pilot develops a perceptual motor skill, the ability to perceive flight characteristics or faults and to respond instinctively with corrective action.

b. To perform this maneuver, a constant heading is maintained while the airplane is rolled back and forth from right to left banks without pause at the wings-level position. Altitude is kept constant. The degree of bank may be increased progressively with skill in performance of the maneuver, or a specified degree of bank may be used. Combining this maneuver with climbs and glides furthers pilot development of control feel, timing, and alertness.

59. Banks With Turns

a. The second elementary coordination exercise consists of banks with turns. The bank is shallow at first, with the angle increased as proficiency develops. The aircraft is allowed to turn while maintaining continuous coordinated flight.

b. A reference line on the ground, normally a straight road or fence row, is chosen and the aircraft flown above and alined with this line. The first turn is started in either direction and allowed to continue until approximately 45° of turn from the original heading is reached, at which time a turn in the opposite direction is started and continued for 90° (45° from the original heading in the opposite direction).

c. The entry of the turn, or roll-in, should be smooth and steady until the desired degree of bank is attained. The change from a bank to one in the opposite direction is continuous, without pause at the wings-level position. The new turn is continued for 90° (45° from original heading in the opposite direction). The airplane may then be flown straight and level until it crosses the reference line or may, as proficiency develops, be rolled from one bank to another as each proper degree of bank is reached. Altitude should remain constant, and all turns fully coordinated.

CHAPTER 12

PRIMARY GROUND TRACK MANEUVERS

60. General

Much Army Aviation flying is at low altitudes and requires frequent and often prolonged observations beyond the confines of the airplane cockpit. Necessarily, then, perceptual motor skills must be developed to such degree that the aviator reacts automatically and safely to flight requirements while keeping most of his attention on mission requirements.

61. Rectangular Course

The rectangular course is an elementary ground track maneuver, but even an experienced aviator may fail to fly a good rectangular course if he does not closely follow well-planned procedures.

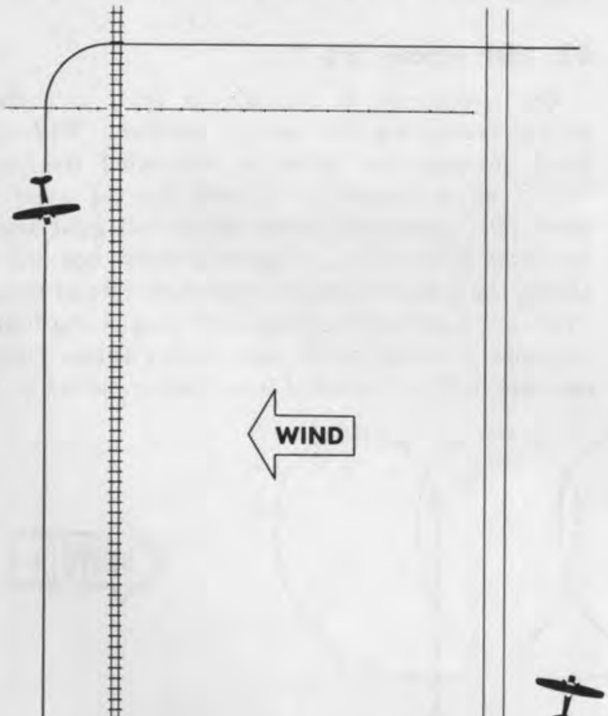


Figure 27. Rectangular course.

a. For the exercise, an area is selected approximately ½-mile square, or as close to this measure as terrain permits, with straight sides and well-defined corners. The airplane is flown around this area, usually 500 feet above the ground, and approximately 1,000 feet away from and parallel to the sides of this area (fig. 27). When flying crosswind, the airplane is crabbed as necessary to maintain a ground track parallel to the area sides. Each turn is started at a point opposite the appropriate corner and timed so as to roll out of the turn opposite the corner at the prescribed distance from the next side to be flown. The arc described over the ground during the turn should be equidistant from the corner at all times; all four turns, put together, should form a circle (fig. 28). The bank varies on each turn, as necessary, to compensate for wind and maintain a constant-radius turn.

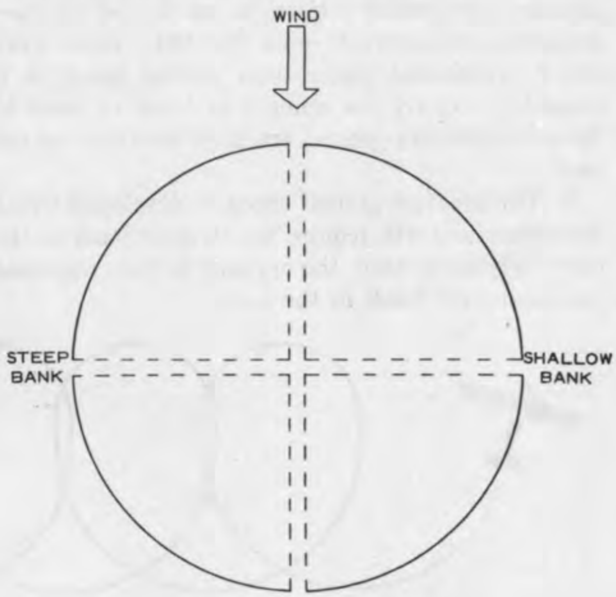


Figure 28. Wind circle.

b. While flying the rectangular course, attention must be divided between outside alinements and control of the airplane. Ground track should be parallel with the area sides and altitude constant; roll-in and rollout of turns must be properly timed and correct variation of bank made to give a constant-radius turn regardless of wind direction. An aviator who thoroughly understands and is able to fly a good rectangular course has the foundation basis for flying the traffic pattern (ch. 13).

62. S-Turns Across a Road

Because wind affects ground track, proper timing of entry and exit of turns is a definite requirement for safe flying. Pilot perceptions during turns near the ground are different from those at higher altitude and can cause misuse of controls which lead to the accidental spin. Benefits gained from the exercise of S-turning across a road, therefore, are a vital part of pilot training.

a. For the exercise, a straight road (or fence line) is selected which runs *perpendicular* to the wind, or as close to perpendicular as possible. The airplane is initially flown either into the wind or downwind to cross the road at right angles, usually 500 feet above the ground. As the road is crossed, a turn is started in either direction and continued through 180°. The turn is timed so that the airplane crosses the road at a perpendicular in straight and level flight. A turn is then immediately started in the opposite direction and timed as in the first turn. The complete turn should make a semicircular ground pattern, the radius of the turn being approximately ¼-mile (fig. 29). Since bank can be controlled easier than ground speed, it is necessary to vary the amount of bank in order to fly a semicircular ground track on each side of the road.

b. The greatest ground speed is developed flying downwind and will require the steepest bank in the turn. Flying upwind, the opposite is true, requiring the shallowest bank in the turn.

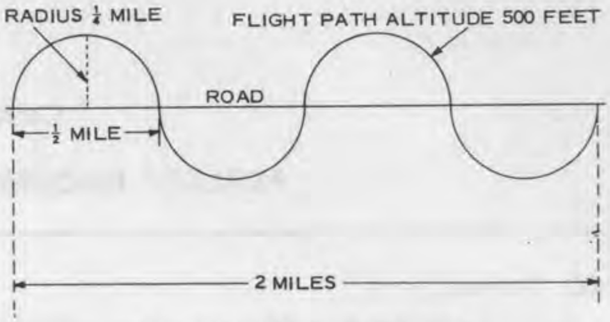


Figure 29. S-turns across a road.

c. Analysis of the maneuver through a complete turn will reveal that the bank begins slowly and is gradually increased throughout the initial 180° of turn. This is because ground speed is constantly increasing. The rollout is quite fast; and, without hesitation, a new bank in the opposite direction is started with a fast roll-in to get the bank established. As this turn progresses, the amount of bank should gradually decrease, since ground speed decreases throughout the second 180° of turn. Altitude remains constant during the the entire maneuver.

63. Elementary 8's

The elementary 8 describes a path over the ground resembling the written number. Without wind, the maneuver is simple; with wind, the maneuver offers important training for the aviator developing perceptual motor skills and good subconscious flying habits. Figure 30 shows how wind affects the ground track at a constant rate of turn. There are many types of figure 8's, progressing from elementary to advanced maneuvering skills. Only one type will be described here—the crossroad 8.

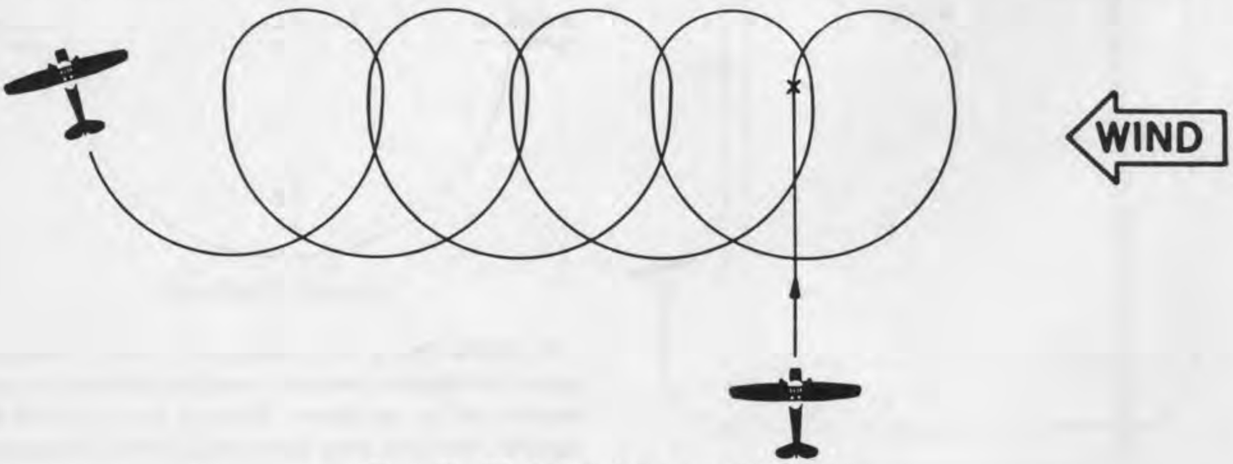


Figure 30. Effect of wind on a constant rate turn.

a. For this maneuver, select a crossroad or an intersection, with one of the roads being as nearly perpendicular to the wind as possible. (Roads offer ready identification of flight position during the maneuver.) The figure 8 is flown so that two circles approximately ½-mile in diameter are tangent at the intersection and bisected by the road perpendicular to the wind (fig. 31).

b. The manuver is normally entered by flying downwind over the intersection at the altitude prescribed for ground track maneuvers. As the intersection is crossed, a turn is started in either direction, with the bank varied so as to complete a circle approximately ½-mile in diameter as the intersection is again crossed. At this time a second turn is started opposite in direction to the first in order to accomplish a second circle on the opposite side of the road intersection.

c. This maneuver requires great division of pilot attention between flying and ground track since each turn involves 360° and a constantly changing bank. As proficiency develops, the maneuver may be entered from any position, but the greatest advantage to the aviator is entry on the downwind side or by flying downwind over the intersection and starting from that point.

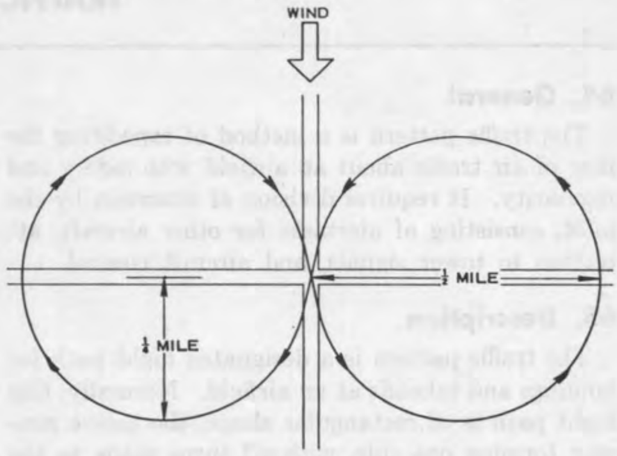


Figure 31. Crossroad 8.

CHAPTER 13

TRAFFIC PATTERN

64. General

The traffic pattern is a method of expediting the flow of air traffic about an airfield with safety and regularity. It requires division of attention by the pilot, consisting of alertness for other aircraft, attention to tower signals, and aircraft control.

65. Description

The traffic pattern is a designated flight path for landings and takeoffs at an airfield. Normally, this flight path is of rectangular shape, the active runway forming one side, with all turns made to the left in forming the other three sides (fig. 32). Each side is referred to as a *leg*: takeoff, crosswind, downwind, base, and approach. The latter occurs after the last turn before landing and is called *final approach.* The normal pattern is flown 1,000 feet above the terrain. The first turn after takeoff may be started before reaching 1,000 feet, but should not be less than 500 feet or until the field boundary is crossed, whichever comes last. If there is other traffic in the pattern, the takeoff leg may be flown straight to acquire adequate spacing between airplanes. (The climb is continued to the designated altitude, which is then maintained.) The turn from crosswind to downwind should be so executed as to place the airplane at the proper distance from the runway. Depending upon the aircraft and the traffic pattern altitude, proximity to the runway may range from 1,000 to 5,000 feet, with 2,000 feet usually adequate.

66. Use

Entry into a traffic pattern is made by flying toward the field at a 45° angle to the downwind leg. This entry reveals pilot intentions and affords excellent pilot visibility for checking the area for other aircraft in the pattern. As the downwind leg is reached just short of the field, the airplane is turned 45° to fly the downwind leg (fig. 32).

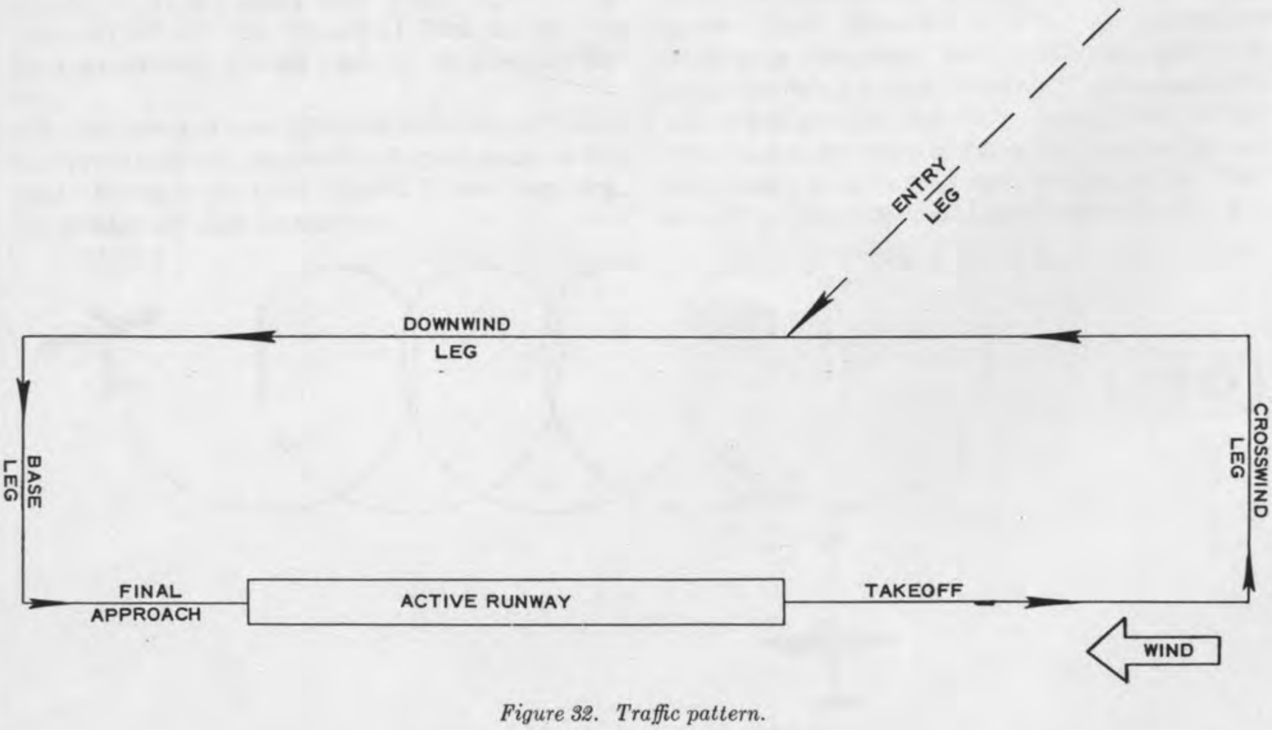


Figure 32. Traffic pattern.

67. Approach

a. Two approaches are normally used for light airplanes: the 180° side approach and the 90° approach. Only the 90° approach will be discussed here.

b. The 90° approach involves only one turn of 90°. On the base leg of the traffic pattern, at a point approximately 45° to the point of intended landing, the pilot closes the throttle and establishes a normal glide. The turn onto final approach is timed to rollout in alinement with the runway. Normal glide is maintained throughout the approach until the *roundout* (breaking the glide, par. 68) is started. If airspeed is allowed to increase above that of normal glide, the airplane tends to "float" during the roundout while dissipating airspeed. If air speed is allowed to decrease below that of normal glide, the roundout may be impossible to complete.

68. Normal Landing

The normal landing for conventional type airplanes is a three-point, full stall landing. The landing is accomplished into the wind to effect a slower ground speed at touchdown. To land, the airplane attitude is changed from normal glide to three-point (fig. 33), and the rate of descent stopped in a manner which permits the airplane to fly parallel with the surface of the runway. This change of attitude and flight path is called the *roundout.*

a. The roundout must be started and timed to attain 3-point attitude, stall, and touchdown almost simultaneously. Application of stick back pressure increases pitch attitude and dissipates airspeed. Stick back pressure is continued smoothly, only with enough force to prevent the airplane from striking the ground prior to obtaining a 3-point attitude. At this time, the airplane should be only inches from the runway, stalled, and almost instantaneously making ground contact.

b. If the roundout is too fast, the airplane will "balloon," causing a gain of altitude; since airspeed is dissipating, the airplane thus may stall at considerable height above the ground. If ballooning occurs, the pilot must compensate with a slight lowering of the nose to get the airplane back to the runway in a 3-point attitude before the stall occurs. This may require slight application of power to prevent the stall, or the pilot may have to effect a *go-around* for another approach because of shortened landing space.

c. If the roundout is too slow, the airplane will strike the ground while descending and either bounce back into the air and possibly damage the landing gear or crash. If the airplane touches the runway before stalling, with descent checked, it will ricochet off the ground with results similar to ballooning. Recovery is effected in the same manner.

d. After contact with the runway, directional control must be maintained to prevent the *groundloop.* Ground steering is by means of rudder, steerable tail wheel, and brakes. If available runway permits, the speed of the airplane is allowed to dissipate with normal ground friction and drag. Brakes are used if needed to help slow the airplane. Maximum braking, if necessary, can be used immediately after touchdown, gradually releasing brake pressure as speed decreases in order to prevent nosing over.

e. Tricycle landing gear generally simplifies the landing touchdown. The location of the center of gravity forward of the two main wheels combines with the forward momentum of the airplane to help hold the airplane on the ground. It also tends to

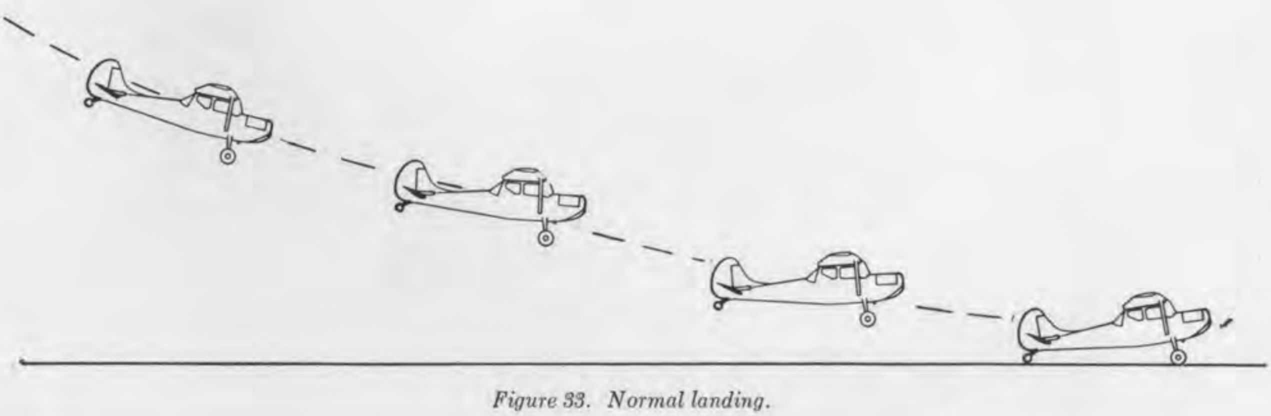


Figure 33. Normal landing.

keep the airplane rolling in a straight path. However, it is not as good as the conventional gear for rough, unimproved fields. The nose wheel tends to dig into the ground on takeoffs, which increases the ground roll and required runway length. The need for this type landing gear is not as great for slower airplanes as for airplanes with high landing and takeoff speeds.

PART THREE

INTERMEDIATE FLIGHT MANEUVERS

CHAPTER 14

INTERMEDIATE GROUND TRACK MANEUVERS

69. General

Pilot sensory perception of the airplane and trained reactions are continuing requirements on an Army aviator's skill. In this respect, ground track maneuvers must be practiced throughout an aviator's career.

70. 8's Around Pylons

This maneuver is primarily designed to develop planning and *sensory-type flying*. Two *pylons* (identification points) are selected about ½-mile apart perpendicular to the wind. The two pylons need not be identical, but both should be easily discernible. Trees, spires, fence corners, water tanks, etc., may be used for pylons. A symmetrical ground track is flown around the pylons while maintaining a constant altitude, usually 500 feet above the terrain. The ground track is in the shape of a figure 8; the tyo pylons are centered in the loops of the 8 (fig. 34).

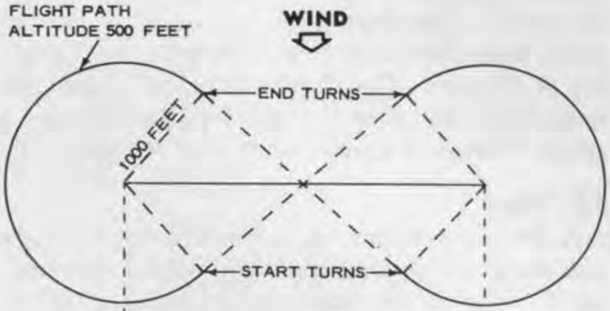


Figure 34. 8's around pylons.

a. The maneuver is begun by flying downwind between the two pylons or by flying parallel to the pylons on the downwind side. All turns are made into the wind. After about 270° of turn, the airplane is rolled out into straight and level flight and flown between the two pylons, downwind, at about 45° to a line connecting the two pylons. As the plane approaches a point where a pylon becomes perpendicular to the flight path, a turn is started around the second pylon. This turn is continued for approximately 270°, at which time the airplane is rolled out straight and level and flown between the pylons at about 45°, downwind, to a point where the first pylon approaches the perpendicular to the flight path. A turn is then started around the first pylon again. The amount of bank used in the turns varies as necessary to maintain a constant-radius circle about a pylon.

b. Figure 34 shows roll-in and rollout. These points vary somewhat with airspeed, wind direction and velocity, and distance between pylons. A fixed reference point on the airplane will not help the pilot during this maneuver since, generally, a constant reference to the pylon while flying the desired ground track is impossible except in a no-wind condition.

71. Steep 8's Across a Road

Steep figure 8's across a road are performed like elementary 8's except for the size of each circle. Steep 8's follow a circular ground track ¼-mile in diameter instead of ½-mile. This requires a steeper bank in the turns, and slight addition of power may be necessary during a turn to maintain airspeed and altitude. The steeper turns require better coordination of flight controls and more pilot attention to the desired ground track. The timing of roll-in and rollout also is more critical than in the elementary 8.

CHAPTER 15

INTERMEDIATE AIR WORK

72. General

The maneuvers explained in this chapter serve a definite purpose in the career of the Army aviator in developing coordination between mind and body and providing knowledge helpful in everyday flying and flight emergencies.

73. Precision Turns—720°

All turns should be made with precision. Turns of 90° or 180° using shallow or medium banks require good coordination for precision accomplishment. However, to continue a turn through 360° or 720° requires a higher degree of perfected coordination, and more exact understanding of control functions. The requirement is still more pronounced if a steep bank is used.

a. A turn of 360° or 720° using a steep bank (generally 60°) is referred to as a *power turn* or a *steep turn*. Steep turns involve the use of all flight controls, generally including throttle for maintenance of necessary airspeed. Entry into a steep turn is like other turn entries, but it is continued until a steep bank has been established. As the bank progresses past that of medium, power is slightly increased to prevent overreduction of airspeed. The turn is continued through 720° and rolled out on the original heading. Flight is coordinated from entry to completion of rollout, with altitude constant.

b. Uncoordinated control will show up quite readily in this maneuver. A definite increase of back pressure in addition to increased power is required to maintain altitude. Control difficulty in the rollout is normal. Back pressure must be released as the bank decreases, and coordinated use of the aileron and rudder maintained. Power is reduced after normal cruising airspeed has been regained.

c. After achieving satisfactory coordination in performing steep turns in each direction, pilot practice of entering one turn directly from another develops further coordination, better understanding of control functions, and improved sensory perceptions.

74. Spirals

A spiral is a gliding turn of 360° or more, usually at a steep bank. The two main types of spirals are the constant bank-and-speed spiral and the spiral about a point. Each type of spiral develops and helps maintain flying proficiency.

a. A constant bank-and-speed spiral helps develop control touch and coordination for power-off conditions. It is entered from a normal glide. After a steep bank is established, the spiral may be maintained for any desired number of turns. Rollout may be on a pre-determined heading or altitude. The entry, spiral, and rollout are coordinated at all times, with airspeed and bank constant.

b. In the spiral about a point, a reference on the ground is selected and the airplane flown to an advantageous position from which a circular ground track of about 1,000-foot radius can be entered. A normal glide is started, and the airplane banked as necessary to maintain desired ground track. Elementary-8 fundamentals are applied to this type spiral to accomplish the constant radius circle about the point. The maneuver is coordinated at all times, and rollout may be on a predetermined heading or altitude. The spiral about a point requires more flying skill than the constant bank-and-speed spiral because of ground orientation requirements.

75. Slips

A slip is a combination of forward and sideward movement, the lateral axis being inclined and sideward motion of the longitudinal axis being toward the lower side. Slips are used for crosswind landings (par. 78) and to dissipate altitude without increasing forward speed. They are so controlled by the aviator as to make the airplane move sideways or to continue the initial flight path over the ground, and may be used during a turn.

a. To establish a slip from a normal glide, the wing toward the desired direction of slip is lowered by use of ailerons. Rudder is used to hold the desired ground track, which may or may not require a change of heading. Gliding speed should be maintained during a slip.

b. Slips are extremely useful if the airplane has no flaps or if the flaps fail to function properly. In the event of a forced landing, the slip enables safe landings in a smaller than normal field or in one which is surrounded with obstacles that hinder a normal approach. Accuracy of landings also may be improved by use of a slip. The slip, however, should not be overused, for judgment of the normal glide may thereby deteriorate.

CHAPTER 16

CROSSWIND TECHNIQUE

76. General

It is impractical to build an airfield with sufficient runways to meet all wind conditions. When using small airfields with a limited number of runways, or a strip with only one runway, proper crosswind technique must be employed.

77. Crosswind Takeoff

Proper application of controls during crosswind takeoff (fig. 35) is as important as when taxiing. The airplane must maintain a straight track across the ground during the takeoff roll to prevent a ground-loop, or side-skip which might lead to a ground-loop.

a. Use of ailerons is the same as when taxiing crosswind, with elevators used initially as in normal takeoff. As the roll increases in speed, aileron use is decreased to prevent the upwind wing from dipping toward the ground; it should, however, be allowed to lower sufficiently to compensate for the wind. Rudder, opposite to aileron, is used to maintain a straight ground roll. The airplane should be held on the ground slightly longer than during a normal takeoff; this will assure its remaining airborne when it leaves the ground.

b. Should the airplane inadvertently become airborne from a wind gust, the pilot must maintain ground track in exact continuation of that on the ground, by means of the lowered wing. In effect, the airplane is slipped into the wind (B, fig. 35) only enough to offset wind drift. This results in a straight ground track parallel to the longitudinal axis and prevents a skip sideways if the airplane returns to the runway momentarily. After the airplane becomes positively airborne, the slip is removed and simultaneously a crab (D, fig. 35) established to correct for wind and provide a faster rate of climb.

78. Crosswind Landing

Successful landings under crosswind conditions are largely dependent upon the ability to fly by sensory perceptions. The aviator must be able to recognize errors and make intuitive corrections. Crosswind capabilities differ with different airplanes, but correction methods are identical for single-engine conventional-geared airplanes. The two methods used for this type airplane are the *wing-low* and *crab*.

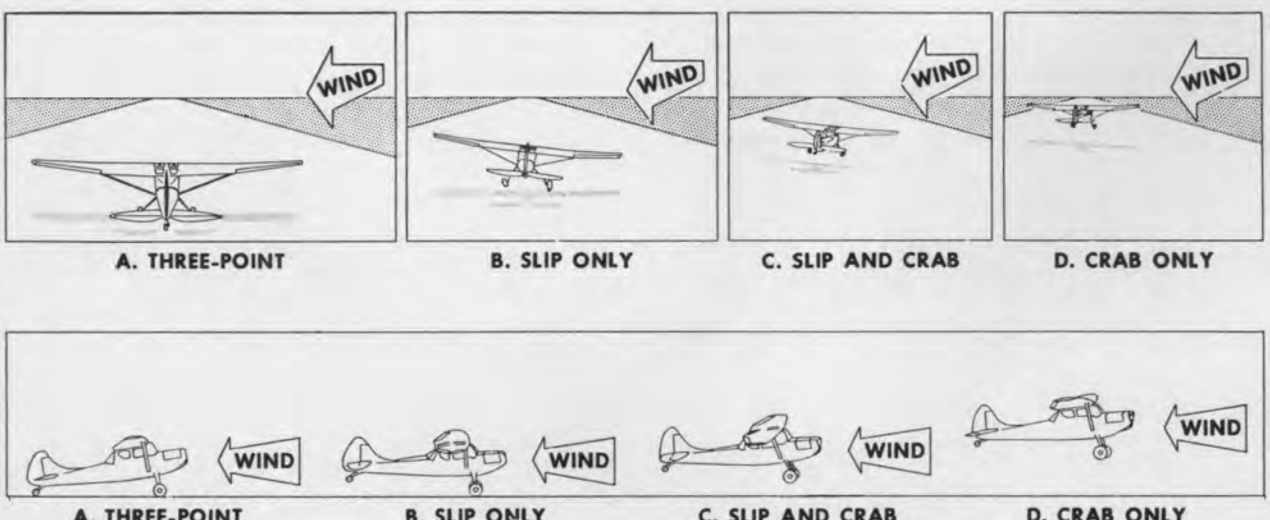


Figure 35. Crosswind takeoff.

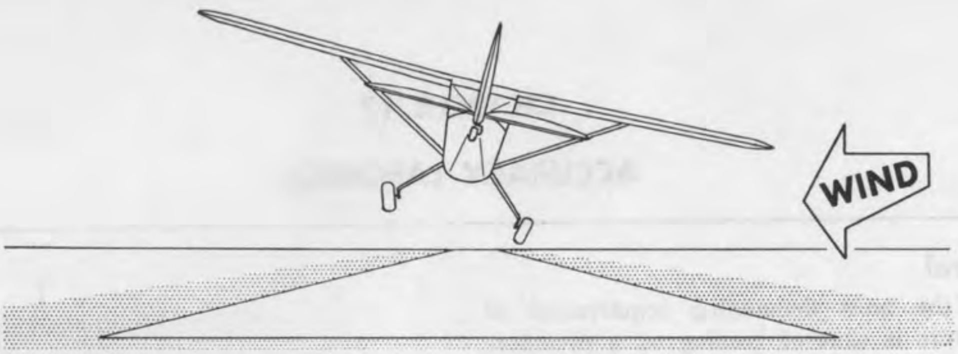


Figure 36. Crosswind landing—slip.

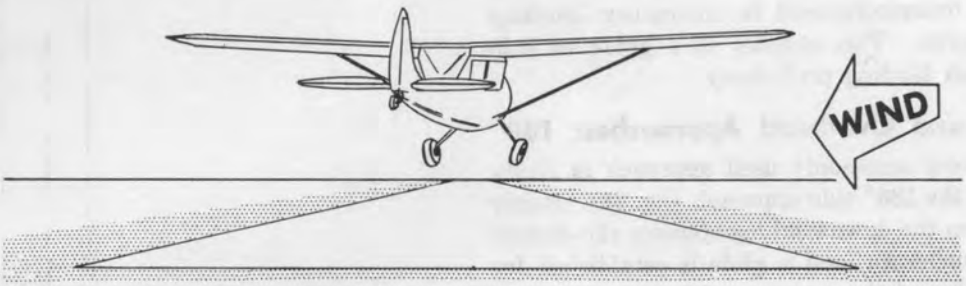


Figure 37. Crosswind landing—crab.

a. The wing-low method is nothing more than a slip into the wind of sufficient amount to compensate for drift. The slip (fig. 36) is normally established as the final approach turn is completed. It is then maintained as necessary throughout the approach and roundout. The airplane will initially touch down on two wheels, the upwind main wheel and tailwheel. As speed decreases, it will tend to settle onto the other main wheel. As this time, the technique for taxiing crosswind is applied to the controls.

b. The crab method (fig. 37) is more difficult since it necessitates better timing during the roundout. Crab required for the wind condition is established on and maintained throughout the final approach. Just prior to touchdown, the crab is removed and the aircraft lined up with the flight path. If the crab is not completely removed prior to touchdown, the airplane will tend to skip sideways on the runway. This may result in damage to the airplane or ground-loop.

c. A combination of the above methods may be employed, the crab method being used initially on the approach and being changed to a slip for roundout and touchdown. This combination method is usually preferable in light airplanes.

CHAPTER 17

ACCURACY LANDINGS

79. General

Perhaps the most demanding requirement of Army aviators is that of landing on a predetermined spot with precision, and doing so repeatedly. Proficiency in this field is mandatory, and its value cannot be overemphasized in emergency landings without power. This chapter is a guide to help develop such landing proficiency.

80. Side and Overhead Approaches: 180°

a. The most commonly used approach in Army Aviation is the 180° side approach (fig. 38). Power is reduced on the downwind leg opposite the desired point of touchdown, and a glide is established for the remainder of the pattern. After power is reduced on the downwind leg, the power-off approach of the downwind leg, the base leg, and final approach should be approximately equal in length. However, if the downwind leg is too far from the field, the base leg must be closer in than normal. This approach, as all the others, requires accurate judgment of gliding capabilities for existing wind and weather conditions.

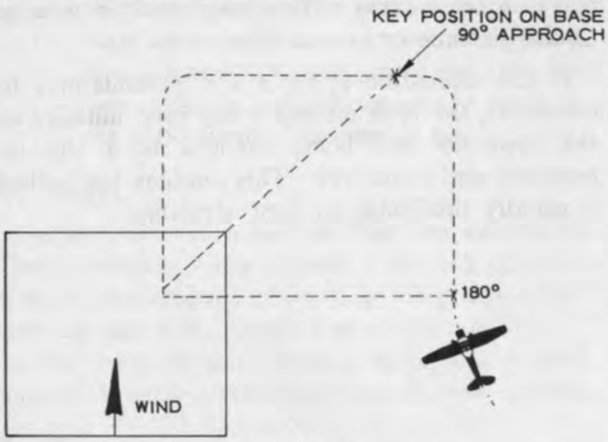


Figure 38. 180° side approach.

b. The 180° overhead approach is initially somewhat more difficult to judge since it requires more turns. Power is reduced while flying downwind, directly over the point of touchdown (fig. 39). The airplane is then turned 45° off the downwind track in either direction and this heading maintained

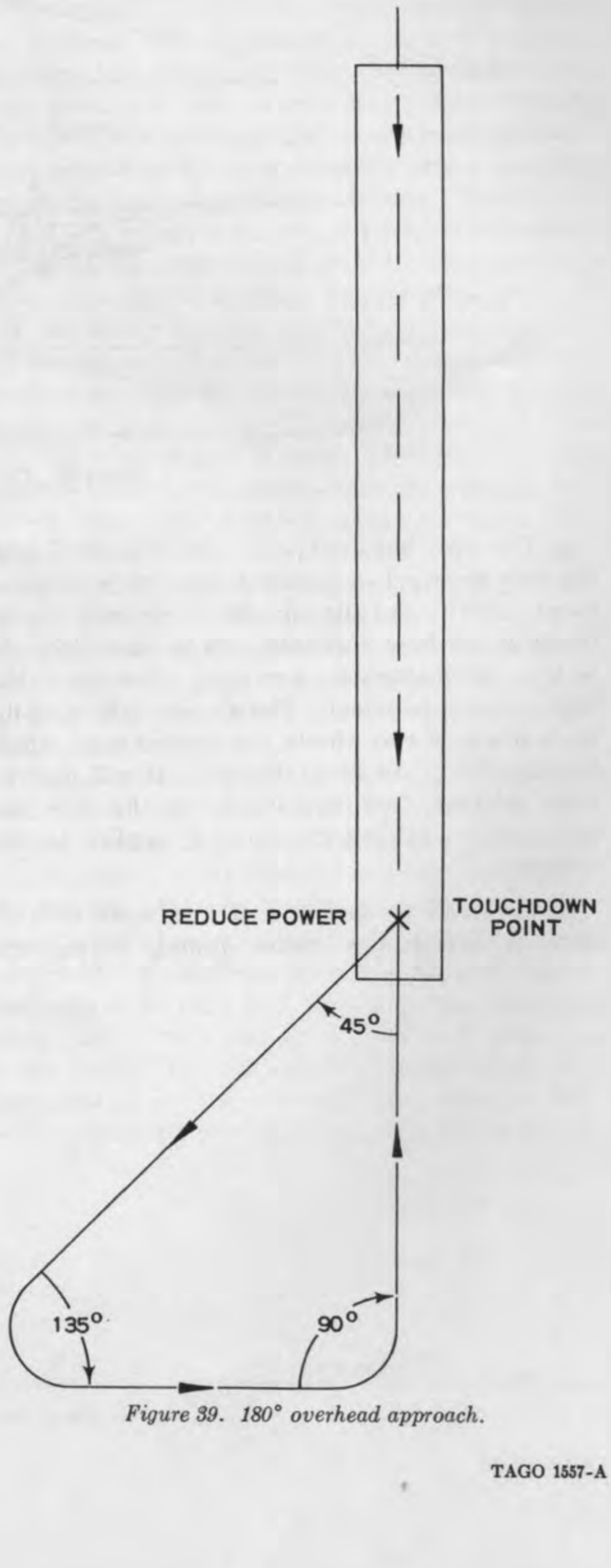


Figure 39. 180° overhead approach.

until ready to turn onto a base leg. This turn is 135° and must be started soon enough to roll out on base leg with sufficient altitude to continue a normal approach without power. If the base leg is too close or too far from the field, the aviator must take supplementary action to accomplish the landing on the predetermined spot. This may require either an early or delayed turn onto final approach.

81. Overhead Approach: 360°

The 360° overhead approach is not often used for a normal landing. It is, however, of great aid to the aviator in maintaining proficiency in glide judgment. The pattern for this approach is shown in figure 40. Flying in the same direction in which the landing is to be accomplished, power is reduced over the desired point of touchdown. A glide is then established for the remainder of the approach. The first turn is 135° in either direction and executed as power is reduced and the glide established. The remainder of the pattern is the same as the 180° overhead approach, the second turn being 135° to place the airplane on base leg. The base leg may then vary as necessary to compensate for error in judgment and to allow arrival at the point of touchdown.

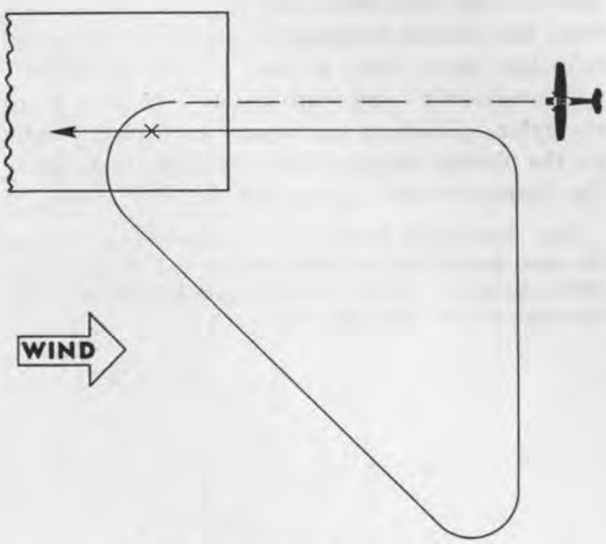


Figure 40. 360° overhead approach.

82. Spiral Approach

The spiral approach normally is used only in event of a forced landing. Its advantages are limited to particular situations; e.g., over swampy or wooded terrain with only one available landing area. The chance of probable error in judgment is lessened since all maneuvering is done in the immediate vicinity of the landing area and touchdown point. The spiral, which is usually performed about the point of touchdown, can be broken off into a pattern for a normal approach from any position at the selected altitude. A steep spiral will result in a fast loss of altitude, while a shallow- or medium-banked spiral will lessen the rate of descent and give the pilot more time for continued planning and execution of the appropriate emergency procedures.

83. Wheel Landings

Wheel landings further develop pilot judgment and timing. In addition, two everyday flying applications are made of them. First, they permit a smoother touchdown, when properly executed, by providing a slower transition of weight from wings to landing gear. Second, they provide more positive rudder control during touchdown because the airplane makes ground contact at higher airspeed. The ground roll of a wheel landing will normally be longer than that experienced in a three-point landing since touchdown is made at higher airspeed.

a. Wheel landings can be made with or without power. Usually the glide is slightly faster than normal to allow more time for roundout. Contact with the runway should be made at a negligible rate of descent, with the tail slightly below that of level flight. As ground contact is made, stick back pressure is released to immediately decrease the angle of attack and prevent the airplane from skipping or richocheting. Release of back pressure must be simultaneous with ground contact.

b. If power is used (very little will be required), it should be added as the roundout is started. This allows the aircraft to settle more slowly if the roundout is too high. As the wheels make ground contact, the throttle is closed and back pressure released.

PART FOUR

ADVANCED FLIGHT MANEUVERS

CHAPTER 18

ADVANCED GROUND TRACK MANEUVERS

84. General

Successful completion of many Army Aviation missions is directly dependent upon the aviator's ability to fly by sensory perceptions. Practice of air-ground visual perspectives helps develop this capability.

85. Steep 8's Around Pylons

The major principles of flying 8's around pylons (fig. 34 and par. 70) are the same whether they are shallow or steep. The only difference is the amount of bank required. Steep 8's generally use a circle one-half the size of the normal 8 (about 400–500 feet in radius). To lessen the amount of straight and level flight between pylons, distance between pylons can be reduced. Since the circle about the pylon is smaller, slight errors are more noticeable. Consequently, more attention must be given to the ground track. This requires a higher degree of sensory-type flying. Proper performance of this maneuver is dependent upon a reasonable degree of proficiency in the normal 8 around pylons.

86. 8's on Pylons

Eights on pylons is probably the most difficult of all ground track maneuvers. It requires almost complete attention outside the airplane and flying almost wholly by sensory perceptions. A constant bank is used, with altitude being varied as necessary. The objective of the maneuver is to maintain a projection of the lateral axis on the pylon during the turn. To do this, a given altitude for a given ground speed has to be maintained; it is known as the *pivotal altitude*. It remains constant for a given ground speed, regardless of the degree of bank or type aircraft (fig. 41). As ground speed increases, pivotal altitude increases; conversely, as ground speed decreases, pivotal altitude decreases. Since the altitude necessary to maintain the desired reference varies with ground speed, the altitude will necessarily vary throughout the turn about the pylon, if there is any wind. In perfectly calm air the pivotal altitude will remain constant during the maneuver since ground speed will not vary.

Note. The pylons selected for this maneuver should be at the same ground level so that entry altitude for each turn will be the same. Amount of bank required will depend upon the radius of turn about the pylon.

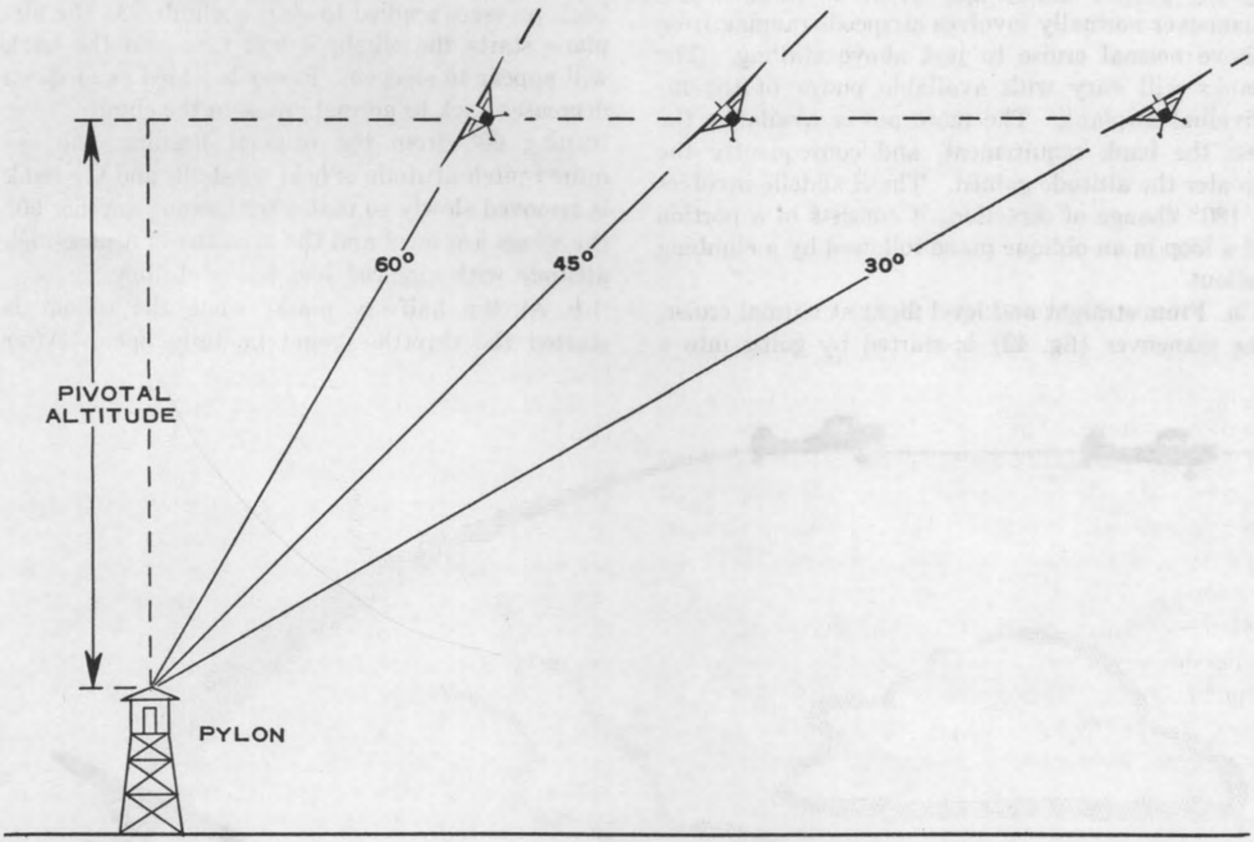


Figure 41. Pivotal altitude.

CHAPTER 19

ADVANCED AIR WORK

87. Chandelles

The chandelle is an advanced coordination exercise in which the airplane is flown at varying airspeed, power, bank, and pitch attitude. The maneuver normally involves airspeeds ranging from above normal cruise to just above stalling. The banks will vary with available power of the individual airplane. The more power available, the less the bank requirement, and consequently the greater the altitude gained. The chandelle involves a 180° change of direction; it consists of a portion of a loop in an oblique plane followed by a climbing rollout.

a. From straight and level flight at normal cruise, the maneuver (fig. 42) is started by going into a shallow dive. After building up some excess airspeed, the airplane is banked in either direction while still in a nose-low attitude. When proper bank has been established, it is held constant and back pressure applied to start a climb. As the airplane starts the climb, it will turn and the bank will appear to steepen. Power is added as airspeed decreases back to normal cruise in the climb. After turning 90° from the original heading, the acquired pitch attitude is held constant, and the bank is removed slowly so that after turning another 90° the wings are level and the airplane in a nose-high attitude with airspeed just above stalling.

b. At the halfway mark, when the rollout is started the throttle should be fully open. After

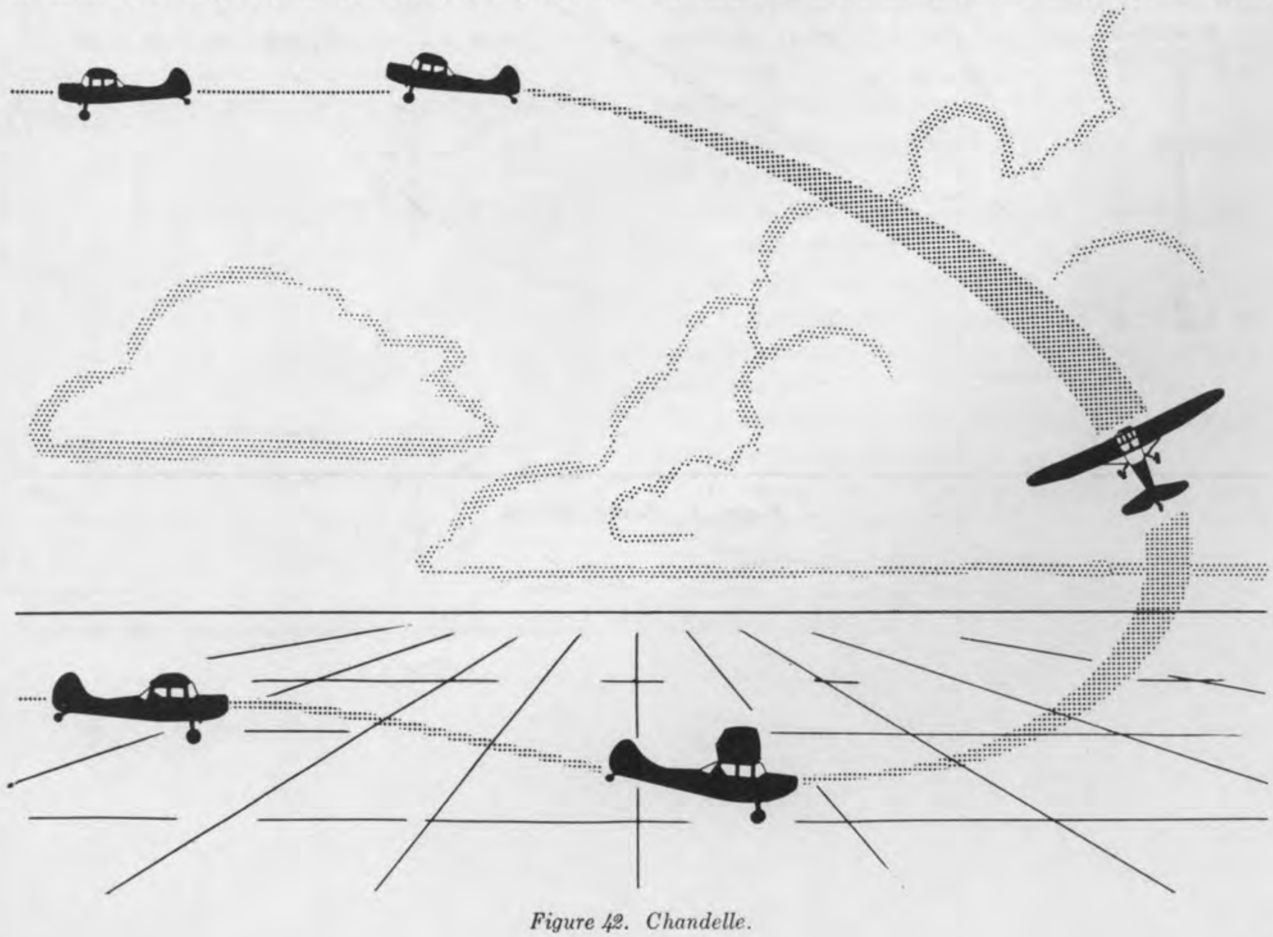


Figure 42. Chandelle.

turning 180° and levelling the wings, the nose is lowered slowly for airspeed to build up to normal cruise without losing altitude. As airspeed increases, throttle is slowly reduced to prevent engine overspeeding, and when normal cruising airspeed is reached power should be further reduced to normal cruise. Coordination must be precise throughout the maneuver.

Note. Although the chandelle is often called an altitude-gaining maneuver, the overall net gain should not be a primary criterion for its performance. Loss of altitude during the initial dive, plus lack of required power in some airplanes, limits appreciable increase in altitude during the maneuver.

88. Lazy Eights

The lazy eight, like the chandelle, is an advanced coordination exercise. Unlike the chandelle, it is wholly a training exercise. For its execution the airplane is flown through a wide range of airspeed and bank and pitch attitudes, with constantly varying control pressures. The lazy eight is unrelated to other 8's previously described because it does *not* describe a figure 8 over the ground, and ground track is irrelevant. The lazy eight (fig. 43) is described by the projection of the longitudinal axis on the horizon and is apparent only to airplane occupants.

a. The lazy eight consists of two 180° turns in opposite directions, entering one from the other, with a symmetrical climb and dive during each turn. The only straight and level attitude during the maneuver is at the moment of passing from one turn to another.

b. To help achieve symmetrical loops in the two turns, a reference point is selected on the horizon 90° from the direction of flight (the cross in fig. 43). During the maneuver, the lateral axis will appear to descend through the reference point as the turn is started, and the longitudinal reference will appear to descend through the ground reference point diagonally, from the 90° point of the turn.

c. The maneuver is entered from normal cruise, flying crosswind, by diving slightly to acquire additional airspeed. After airspeed has increased, a shallow climb is started. As the airplane passes through level flight attitude, a turn is started toward the reference point. At this time the inside wingtip will appear to pass down through the reference point. Bank is constantly increased through the first 90° of turn. The pitch attitude should start decreasing after 45° of turn to bring the longitudinal axis level after 90° of turn; the longitudinal reference on the airplane will then appear to pass through the ground reference point.

d. At this time a slow rollout is begun. The nose continues downward, entering a shallow dive while bank is being decreased. As airspeed again builds up to slightly above normal cruise, the nose will start upward. As it passes upward through level flight, the wings should be level, with the airplane flying 180° to the original heading.

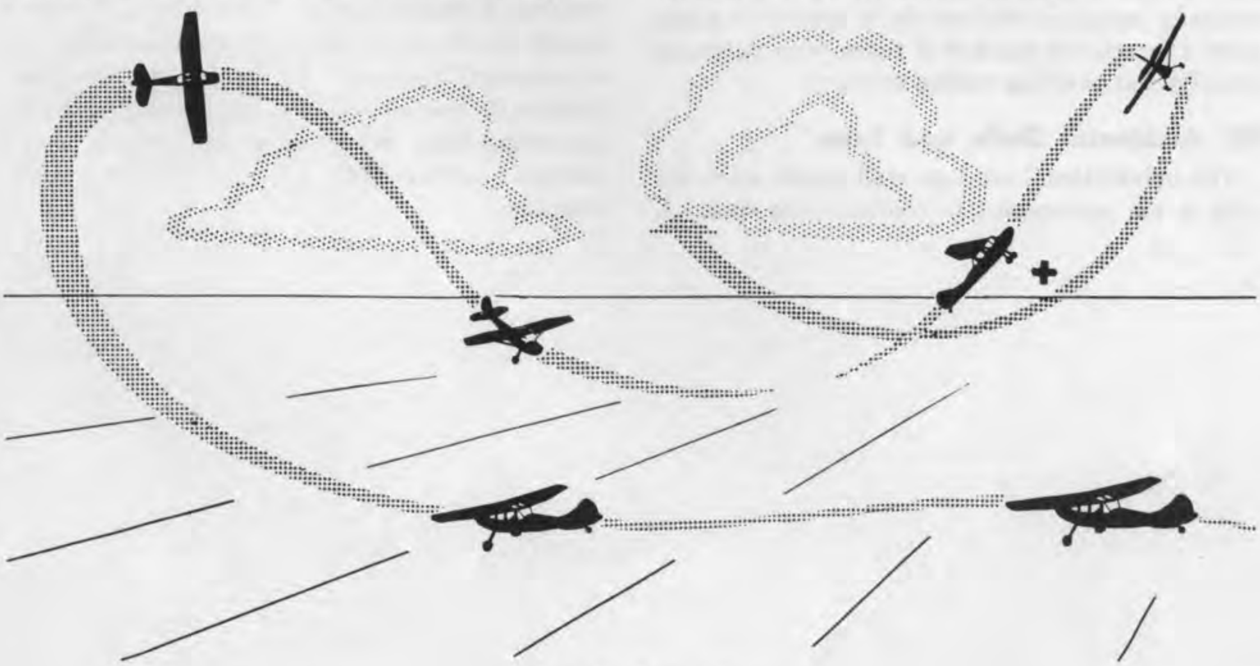


Figure 43. Lazy eight.

e. Without pausing at level flight, a climbing turn is started in the same manner as the first, but in the opposite direction. As the turn is started, the inside wing will again appear to pass down through the reference point. The climb and turn are continued until just above stalling airspeed, at which time a slow transition to a dive is started. After turning 90°, a slow rollout is started as the longitudinal axis passes through the reference point. The dive continues, decreasing in pitch as the rollout progresses. As airspeed again increases to above normal cruise, the nose will rise to level flight, at which time the wings should be level and the longitudinal axis positioned to carry the inside wingtip directly above the horizon reference point. The airplane will be on the same heading as when the maneuver started.

f. Throughout the maneuver, the airplane should be flown with precise coordination, planning, feel, and sensing. Continual small corrections usually will be required and should be made using control combinations to maintain coordination. Because of the requirement of constantly varying control pressures, practice of this maneuver develops greater flying skills for accomplishment of the Army Aviation mission.

89. Precision Spins

Precision spins are essentially elementary spins, the entry and spin being executed in an identical manner. However, precision spins require better control and spin orientation. The precision spin normally requires recovery on a specific heading after a preselected number of turns, with minimum slipping and skidding during recovery.

90. Accidental Stalls and Spins

The unintentional airplane stall occurs when the pilot is too preoccupied to recognize the stall. A spin may follow, and the normal spin recovery will be necessary. If, however, the unintentional stall and resulting spin happen near the ground, there may be insufficient altitude to effect recovery. *It is of utmost importance that the pilot understand conditions and circumstances which may lead to stall and spin disaster.*

a. Accidental stalls and spins may result from prolonged steep turns. Since a slight amount of top rudder is a common pilot error in steep turns, the airplane has a tendency to spin toward the outside of the turn. The resulting stall is the same as any other, but at a higher speed and in a different plane. If slight bottom rudder is being held as the stall occurs, the airplane will spin toward the inside of the turn. Since the airplane will have stalled at a higher than normal airspeed, throttle should be closed immediately to prevent further excessive strain. Normal spin recovery techniques will effect recovery.

b. Under certain conditions, sudden application of aileron or power may cause the airplane to spin. Perhaps the most frequent and fatal accidental spin is the inside spin since it frequently happens at low altitude, particularly during a turn in the traffic pattern. The pilot tries to tighten the turn with bottom rudder without increasing bank and the spin then happens.

c. If subconscious flying skill has not been properly developed, the pilot fails to notice excessive skidding during the turn. Even if he is fortunate enough to survive, he probably will not realize how he managed recovery. Only properly developed flying skills provide feel or sensing of this extremely precarious flight development and permit proper corrective action with time to recover at low altitudes.

PART FIVE

TACTICAL FLIGHT TRAINING

CHAPTER 20

SHORT FIELD AND ROAD STRIP TECHNIQUE

91. Power Approach

a. The power approach is used to accomplish touchdown accuracy and the shortest safe ground roll. The shortest safe ground roll is accomplished by maintaining the slowest safe ground speed during approach, with the minimum airspeed which will provide a safe margin above stalling. This airspeed will vary with different airplanes, loads, and weather conditions, such as temperature, relative humidity, wind, and density altitude. To assure minimum safe airspeed consistent with prevailing conditions, a certain pitch attitude should be approximated. This attitude is the highest pitch attitude which would sustain controlled flight with power removed, and is commonly referred to as "power approach" attitude. Use of attitude rather than airspeed allows the pilot the freedom of devoting attention outside the cockpit, yet provides for immediate recognition and correction of error on the glide path. Rate of descent is controlled by the throttle, maintaining a glide path which approximates that of normal glide. Flaps are normally used for the power approach.

b. There are many important factors to be considered by a pilot before landing in short, strange fields. Two of these factors are the "touchdown" and "go-around" points.

(1) The touchdown point is the place on the ground selected by the pilot in which the aircraft is to land. It should provide maximum usable distance for the ground roll after landing. If barriers exist at the approach end of the landing area, the point of touchdown must be far enough away from the barrier to provide a safe approach angle over the barrier.

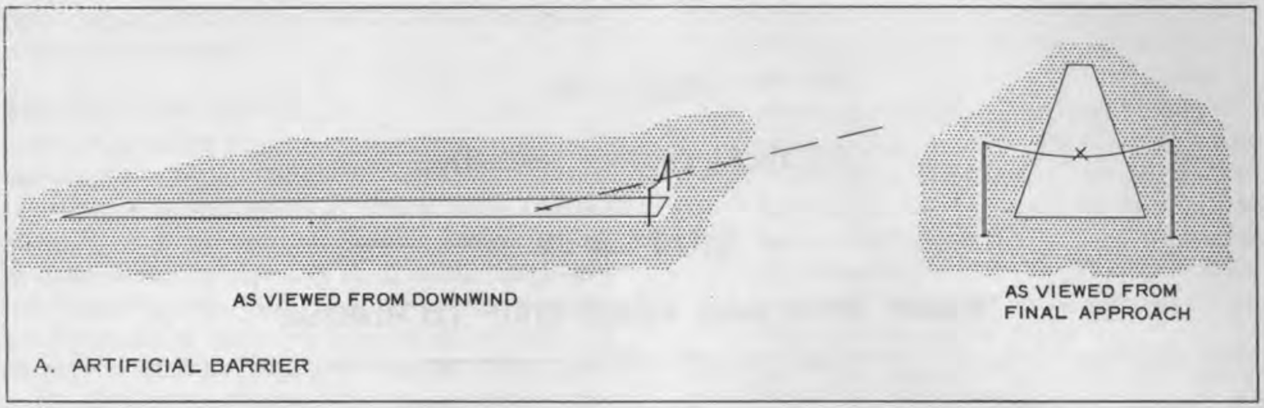
(2) The go-around point is a point selected by the pilot from which either a safe landing roll or a safe go-around can be executed. Its location will vary from a position on final approach prior to the touchdown point to a place further down the landing area beyond the touchdown point, depending upon the length of usable strip, wind, and barriers.

c. The power approach is normally started from a 180° side approach. Usually a normal glide is used until the aircraft is on the required glide path, then the power approach is started. If the approach is made to an open touchdown point, the pilot must visualize the proper glide path and maintain it. If there is a barrier at the approach end of the landing area, the pilot can use the sight picture method to help visualize and maintain the glide path (A and B, fig. 44).

d. The roundout is started later than in a normal power-off approach since less change of pitch attitude and airspeed is required to accomplish the landing. It is started in sufficient time to stop the descent, attain a three-point attitude, and make ground contact at the touchdown point; these are accomplished simultaneously. Power reduction is started just before reaching the three-point attitude to prevent floating tendencies; reduction should be slow enough to prevent early stalling. Normal crosswind technique is used as necessary. After the landing, brakes are used as essential to prevent running off the end of the usable landing area. If hard braking action is required, it should be used initially after touchdown. As the ground speed decreases, the braking action also must decrease to prevent the aircraft from nosing up or somersaulting onto its back.

92. Maximum Performance Takeoff

a. The maximum performance takeoff is designed for takeoffs from small, rough landing areas with minimum ground roll. Loss of ground drag allows



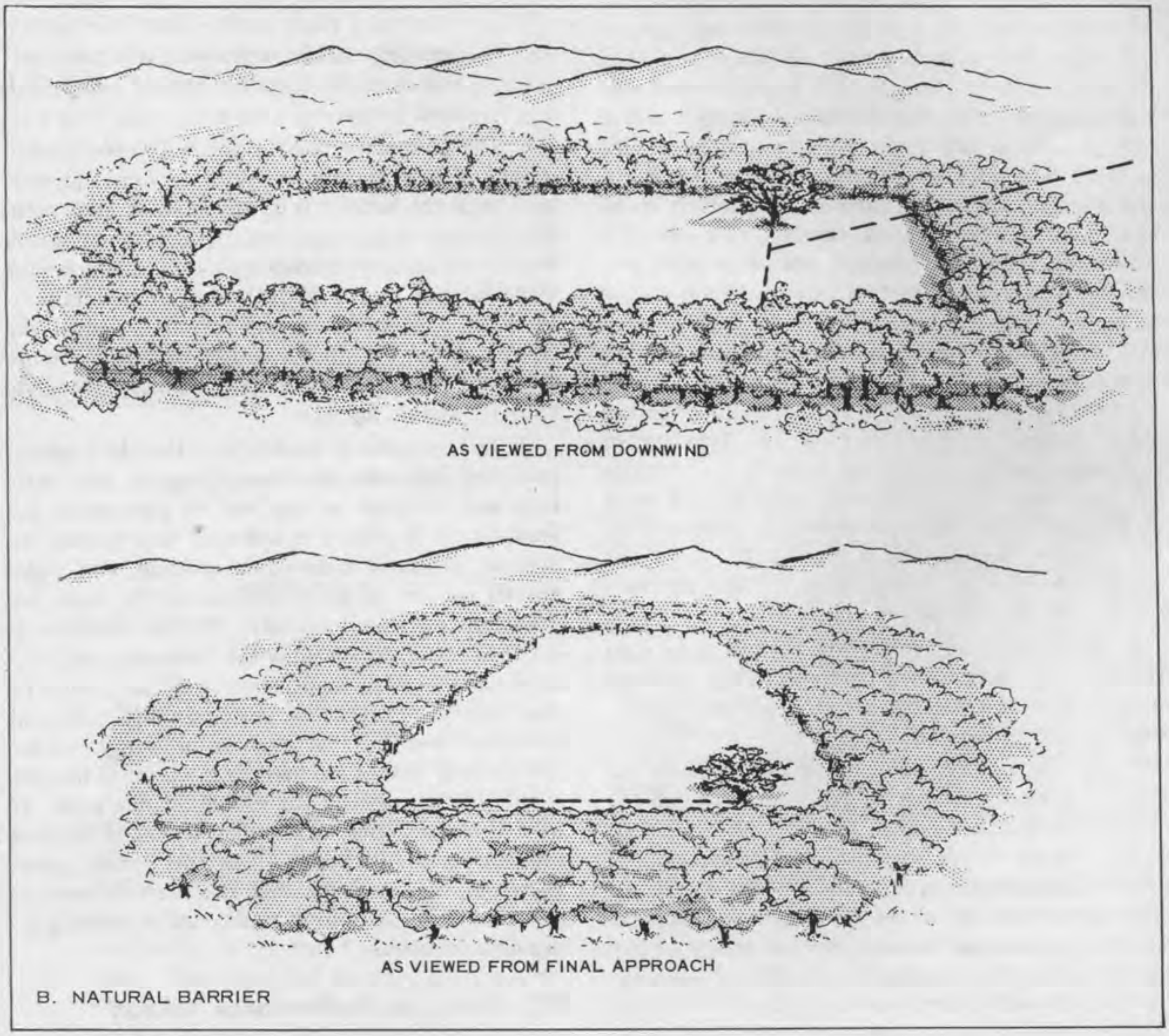


Figure 44. Barrier sight picture.

the airplane to accelerate faster off the ground and leads to a normal climb in less horizontal distance than in normal takeoff.

b. For minimum ground roll, maximum permissible power is used. The throttle is advanced with the stick full back while holding the airplane in the takeoff position with brakes until maximum permissible power is reached. Ground roll begins by releasing the brakes followed by relaxing back pressure; directional control is accomplished by use of the tail wheel, or nose wheel, rudder and ailerons. Further use of brakes is avoided except for emergencies.

c. The airplane is flown from the ground in a tail-low attitude. After leaving the ground, pitch attitude may be increased to achieve the maximum angle of climb for clearing a barrier. Once the barrier is cleared, a normal climb is assumed. If there is no barrier, normal climb is assumed after the airplane becomes airborne. Crosswind control is the same as in a normal takeoff. A crab is established as soon as possible after takeoff to obtain maximum lift.

93. Flight Reconnaissances

Since much of the flying required of Army Aviation is from unprepared strips that sometimes have multiple uses, the aviator must be sure the strip is usable before attempting a landing. This is determined by means of a thorough reconnaissance, which is divided into two phases—*high* and *low*. To prevent disclosing location of the strip, these reconnaissances must be made with a minimum of flying commensurate with safe, accurate observations.

a. High Reconnaissance. During the high reconnaissance, the strip is surveyed as accurately as possible, checking its length, slope, direction, obstacles (on the ends or sides), and available forced landing areas (for both landing and takeoff). After considering these facts, the directions of landing and takeoff are tentatively selected, and tentative points of touchdown and go-around are chosen. The direction and area of flight for the low reconnaissance is also selected. If the strip is on a road, particular attention must be paid to ditches, culverts, bridge and culvert abutments, power and telephone lines (either parallel to or crossing the strip), and road signs which a wing or strut might hit. Traffic on the road must also be considered. No particular flight pattern or altitude is prescribed for the high reconnaissance.

b. Low Reconnaissance. The low reconnaissance normally is made in the same direction as landing

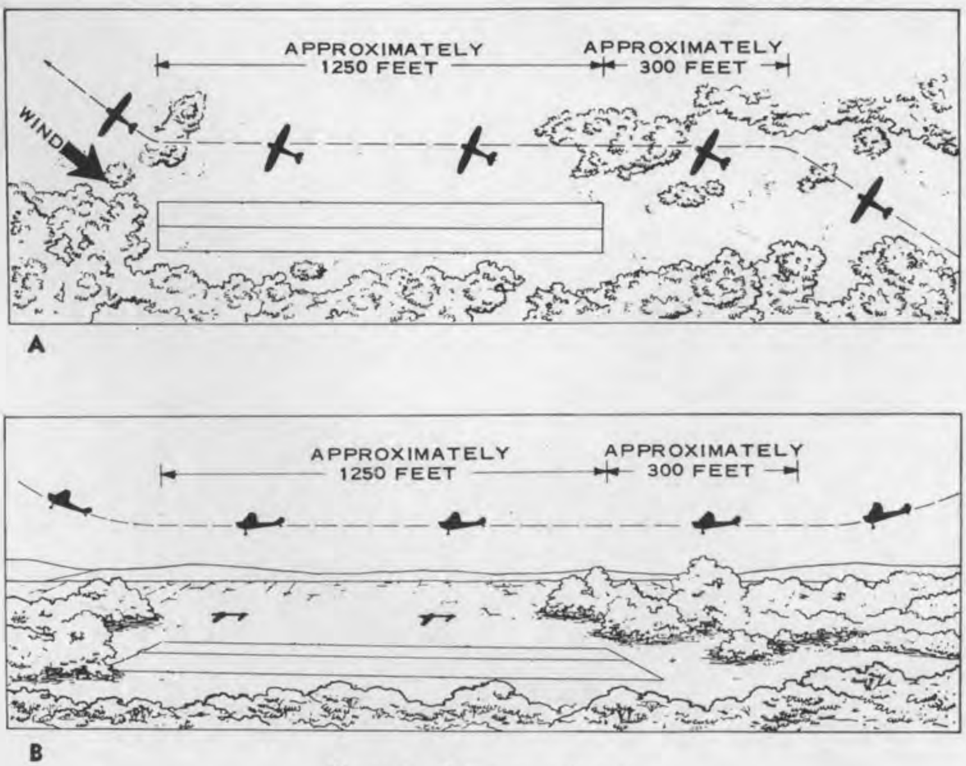


Figure 45. Low reconnaissance.

and takeoff. However, if these directions differ, low reconnaissance normally will be made in the direction of takeoff. The altitude (A, fig. 45) and flight path (B, fig. 45) for the low reconnaissance is such that the pilot is able to see all of the strip by looking out the side of the airplane at an approximate 45° angle to the ground. Altitude should provide a safe margin above the highest obstacle in the flight path. The side on which to make the low reconnaissance is governed by such factors as wind, forced landing areas, and obstacles. It is generally best to select the side that will allow observation with a minimum of obstructions to vision at the lowest possible altitude. During the low reconnaissance, the surface of the strip is inspected for suitability of use (watching for holes, rocks, stumps, or anything else that may prove hazardous to a landing). Touchdown and go-around points are confirmed. If it is an area strip with more than one possible landing lane, only that portion of the area selected for the landing should be scanned; the remainder of the area can be better evaluated after landing. Discoveries during the low reconnaissance may necessitate changes to the original plan of landing. Newly discovered features must be analyzed, alternate possibilities weighed, and a sound decision made promptly in order to eliminate unnecessary flying about the selected landing site.

94. Ground Reconnaissance

A ground reconnaissance is performed to determine the operational capabilities of the strip, with primary emphasis on safety factors. Taxiing on the strip is avoided except under the direction of ground personnel or after completing a thorough ground inspection. During the ground reconnaissance, such items as length and width of usable strip, condition of the surface of the entire strip, location and type of barriers, overall size for operational requirements, and tactical features must be considered to determine the feasibility of using the strip. If immediate takeoff is contemplated, wind direction is checked and takeoff direction confirmed. The best position for takeoff is selected and the takeoff land double-checked for its safety. Ground reconnaissance of road strips also includes checking ditches, culverts, lateral clearance, and turn-around areas.

CHAPTER 21

FORMATION FLYING

95. General

Precision formation flying can only be achieved through first hand experience over a period of time. Fundamentals discussed in this chapter will aid the pilot in understanding basic elements involved in formation flying.

96. Types of Formations and Terminology

Many different types of formations arise from the basic ones given in *a* through *d* below. Only after considerable proficiency and teamwork have been achieved in these basic formations should more difficult ones be attempted by the Army aviator.

a. The basic element for all formation flying is the two-plane formation. The airplanes are referred to as "leader" and "wingman," or numbered "1" and "2" as shown in figure 46. This type formation is not often used in Army Aviation.

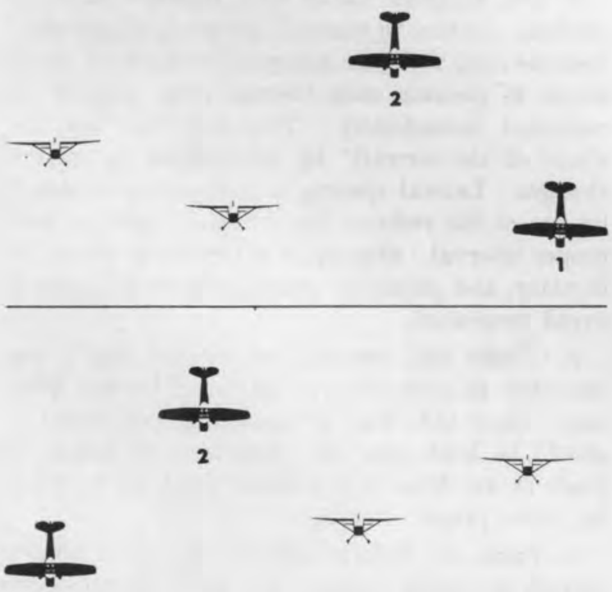


Figure 46. Two-plane formation.

b. The next type formation, and the one probably most used in Army Aviation, is the **V**-formation, consisting of three airplanes. They are numbered as shown in figure 47, which also indicates desired spacing. Due to the relatively slow speeds of Army airplanes, extremely tight formations should be avoided.

Figure 47. **V**-*formation.*

c. The third type formation, common to Army Aviation, is echelon, either right (A, fig. 48) or left (B, fig. 48).

d. The last of the basic type formations is the "trail" formation. As the name implies, all aircraft are in trail, one behind the other. Spacing and positions for this type formation are shown in figure 49.

Note. By using various combinations of the above basic formations, more advanced formations can be made.

e. Formation flying has terminology peculiar to it. Some of the elementary terms of formation flying are as follows:

(1) *Element*—basic working unit of either two or three aircraft.

(2) *Interval*—the fore or aft distance between aircraft in an element, or between elements in a larger formation.

(3) *Lateral spacing*—the side to side distance

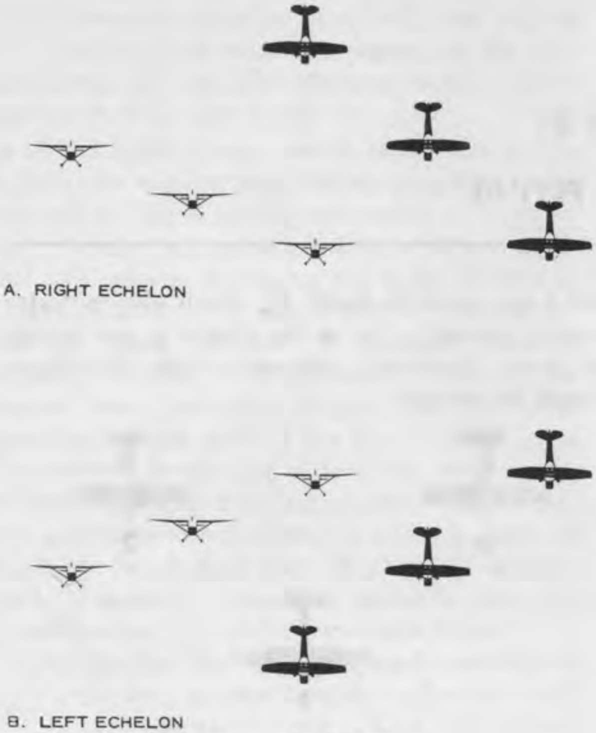


Figure 48. Echelon.

between aircraft in an element, or between elements in a larger formation.

(4) *Step-up or step-down*—the vertical distance between aircraft in an element, or between elements in a larger formation.

(5) V-*formation*—the basic formation for three aircraft, as shown in figure 47.

(6) *Echelon*—a formation in which the wingmen form a diagonal line above, behind, and to one side of the leader. Always designated left echelon or right echelon (fig. 48).

(7) *Rendezvous*—a prearranged assembly point at a selected altitude, used for joining up after individual takeoffs.

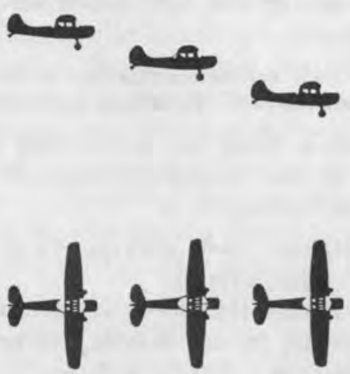


Figure 49. Trail formation.

97. Communications

a. Both visual and radio communications are employed to control and guide the formation element or elements. Visual signals may be a movement made by the pilot, or brief, slight changes of aircraft attitude of the lead plane. Due to lack of adequate pilot-to-pilot visibility in most Army aircraft, visual signals normally are limited to those accomplished by changes of aircraft attitude.

b. Radio communications are more advantageous in Army airplanes than visual signals. The use of radio depends upon availability of a frequency for interplane communications. Even with a frequency assigned for this purpose, transmissions should be kept to a minimum consistent with completeness and clarity of instructions.

98. Elementary Techniques

a. The lead aircraft is the control aircraft in all formation flights except by other prior arrangement. The leader is responsible for keeping the element clear of all other aircraft. He gives all signals, visual or radio, to change heading or altitude. Since all spacing for the formation is taken from his aircraft, he must maintain constant speeds, headings, and altitudes; changes must be smooth and precise.

b. The wingman has to keep constant watch on the lead airplane to maintain proper spacing, which requires close vigilance and quick corrections. Small errors in position soon become large ones if not corrected immediately. This requires "planning ahead of the aircraft" by anticipation of possible changes. Lateral spacing is maintained primarily by use of the rudder; the throttle is used to keep proper interval. Step-up is achieved by use of the elevator, and should be maintained at all times to avoid prop-wash.

c. Climbs and descents are entered slowly and smoothly to prevent overcontrolling by the wingmen. Once the climb or descent is established, it should be kept constant. The level-off should be made slower than in individual flight for wingmen to retain proper spacing.

d. Turns are entered slowly and are generally limited to shallow banks. The lead aircraft enters the turn at normal cruise; the inside wingman reduces power and adjusts as necessary to maintain spacing and the outside wingman adds power and adjusts as necessary. When in echelon formation, all aircraft must make power adjustments. When the leader is on the inside of a turn, he must reduce power while the wingmen must increase power.

99. Advanced Techniques

a. Change of leader should be attempted only after prior arrangement and thorough preflight briefing. To accomplish it, the lead aircraft signals a break-up. The new lead aircraft then passes to the front and signals for a join-up. The new leader uses slightly less than normal cruise power for a faster join-up.

b. The crossover is a precision change of position, with emphasis on economy of space and time. It should be attempted only in straight and level flight, and then only after thorough preflight briefing by the formation commander.

(1) *"V" to left echelon* is begun with the leader and left wingman holding their positions. The right wingman doubles his step-up; then, keeping his wings level, employs enough rudder to slide over and to the left rear of the left wingman. Throttle adjustments achieve proper interval at the same time lateral spacing is reached. *"V" to right echelon* is executed in a similar manner, with left wingman making the change while the leader and right wingman hold steady.

(2) *Left echelon to "V"* is begun with leader and center man (left wingman) holding steady. The rear man slides over to the right of the leader, adding throttle to achieve proper interval at the same time lateral spacing is reached. He then promptly reduces his step-up to normal. *Right echelon to "V"* is similar, with the rear man going left instead of right.

(3) Crossovers need not be limited to basic elements. Elements in a formation may change over to produce a formation in echelon of V's either right or left. There are many possible combinations, but they should be attempted only by seasoned pilots who work together over an extended period of time.

c. The *formation takeoff* should be attempted only after long experience in flying. Wingmen must be extremely vigilant to preclude accidents since it is more difficult to avoid other aircraft while on the ground. The leader clears the area and requests takeoff clearance for the element. Wingmen follow the leader onto the runway and space themselves as liberally as area permits. They then apply partial power while holding brakes, to be ready for the signal for the roll. After receiving this signal, slow, smooth application of the throttle by the leader aids the wingmen in keeping proper spacing. The leader does not use full power, and he holds his aircraft on the ground until wingmen are airborne; he then starts a shallow climb. Prearranged power settings and airspeeds will help the wingmen fly a more precise formation during takeoff and climb-out. Flaps are not normally used for the formation takeoff.

d. When landing in formation, the leader receives landing clearance and clears the proposed approach path. A shallow approach at a prearranged airspeed is made. As the element nears the touchdown, the wingmen start increasing interval and lateral spacing. For greater safety, the leader should hold off his own touchdown until the wingmen have touched down. Flaps are used as necessary, application being slow so that wingmen can follow and maintain formation.

e. In formation where many elements are involved, interval between elements should be approximately 150 feet. Training elements normally will employ a step-down from the lead element, keeping the lead element in sight above the horizon and avoiding its prop-wash. If such formations are used for resupply, however, training elements must employ the step-up to avoid falling bundles and parachutes from the preceding elements.

CHAPTER 22

EVASIVE MANEUVERS

100. Contour Flying

The best defense for a light airplane against an attacker, either from the ground or air, is contour flying. This is low-altitude flying in which the flight path conforms in general to terrain contours. The aircraft presents a poor target because of its constant changes in position and, to ground fire, exposure is generally abrupt and of short duration. Furthermore, contour flying conceals landing areas and flight routes from enemy observation.

101. Contour Flying Risks

Certain risks, however, accompany contour flying which are not common to normal flight at higher altitudes. The aviator must be constantly alert for obstructions, particularly for telephone and power lines. Precarious flight positions, such as abrupt pullups and excessively steep banks, should be avoided, and care must be taken not to lower a wing into ground obstructions even in gradual banks. Although valleys offer good concealment from enemy observation, the aviator must assume, if the area is unfamiliar, that wires are strung between the hills. Identical assumption must be applied to any inviting gap between ground obstructions.

102. Contour Approach

Benefits gained from contour flying may be lost if a normal approach pattern is used in the landing. The contour approach is employed to offset this disadvantage. For this type of approach, throttle should be reduced far enough from the landing area to dissipate excess airspeed while maintaining altitude approximately equivalent to that used during contour flying. Flaps may be added for further dissipation of airspeed. As the field boundary comes into pilot view, a low-altitude power approach is begun. Slipping the aircraft should be avoided except to prevent a go-around.

103. Use of Aerial Maneuvers

If attacked by enemy aircraft or ground fire, the only effective evasive action for the light Army airplane is to make rapid changes in altitude and/or direction; e.g., spins, split S's, and steep diving turns as altitude permits. Caution must be exercised to avoid obstructions and a high speed stall during the pull-out.

APPENDIX I

REFERENCES

AR 95–5	Army Aviation; General Provisions.
AR 95–8	Flight Regulations for Army Aircraft.
AR 95–11	Flight Service Interphone Communications Systems Procedures.
AR 95–14	Army Aviation Flight Information.
AR 95–15	Aerial Flights; Piloting Aircraft; Parachute Jumps.
AR 95–31	Flying Time, Duty, Transition Training, and Proficiency.
AR 95–32	Annual Minimum and Maximum Flight Requirements for Army Aviators.
AR 95–63	Instrument Certificates Requirements, and Aircraft Suitability.
AR 95–64	Individual Flight Record File.
AR 95–70	Army Aviation Flying Hour Program.
AR 95–85	Safety Procedure for Aircraft Operation and Movement on the Ground.
AR 95–110	Identification and Security Control of Military Aircraft.
SR 320–5–1	Dictionary of United States Army Terms.
AR 320–50	Authorized Abbreviations.
AR 715–232	Emergency Purchase of Fuels, Oils, Parts, Supplies, Equipment, and Necessary Services from Commercial Sources.
DA Pam 108–1	Index of Army Motion Pictures, Filmstrips, Slides, and Phono-Recordings.
DA Pam 310-series	Military Publications Indexes (as applicable).
FM 21–5	Military Training.
FM 21–6	Techniques of Military Instruction.
FM 21–30	Military Symbols.
TM 1–215	Instrument Flying; Theory and Procedures.
ATRC Manual 51–3	Principles of Flight.
CAA Bul No. 26	Aerodynamics for Pilots.
CAA TM No. 100	Flight Instruction Manual.
CAA TM No. 105	Flight Instructors' Handbook.

APPENDIX II

CARE AND USE OF THE PARACHUTE

1. General

Before you start flying you should be thoroughly familiar with the various items of flight equipment, especially those items that are provided for your safety. One of the most important of these items is the parachute. Without a thorough background on WHEN, WHY and HOW to use it, it will be of little value to you as an item of safety equipment.

2. Construction

Most of the personnel parachutes used by Army aviators are of the back and chest types (fig. 50), each of which has a 28-foot canopy. The airplane to be flown normally will dictate the type of parachute to be used; however, the back pack (A, fig. 50) is the most common.

a. Generally speaking, the parachute is composed of two parts, the harness and necessary padding (C, fig. 50), and the pack (B, fig. 50) which contains the canopy. The harness is usually constructed of specially woven lines with a tensile strength of at least 5,000 pounds. It can be adjusted to the individual's body with straps, buckles and fittings. Most of the metal used for the hardware is made from cadmium-plated chrome nickel steel or from polished stainless steel.

b. The parachute canopy is of high grade silk, nylon, or pongee. An air vent is provided at the top of the canopy to help steady the parachute as it settles toward the earth. Without this vent, oscillations would be great and, for the most part, uncontrollable.

Figure 50. Back and chest pack parachutes.

c. A "pilot" chute fastened at the top of the main chute is popped out of the pack by steel springs when the ripcord is pulled. This chute catches the air and draws out the main canopy. Without the pilot chute, canopy opening would be slow and the wearer's body might become entangled in the canopy and suspension lines, thereby fouling the chute and rendering it useless.

3. Inspection

Each time you receive a parachute, you should perform a preflight inspection on it, just as you perform a preflight inspection on an airplane. This general inspection ascertains whether or not the chute is in proper condition for use. It should include the following:

a. Check the log book for proper entries. The parachute must be repacked every 60 days and have a routine inspection every 10 days by either a qualified parachute rigger or a qualified pilot. If a greater time has expired, the parachute should be refused and another obtained in its place.

b. Check the general condition of the harness and pack, looking for rips, loose threads, bent hardware, and stains caused by liquids, such as water, oil, or acid.

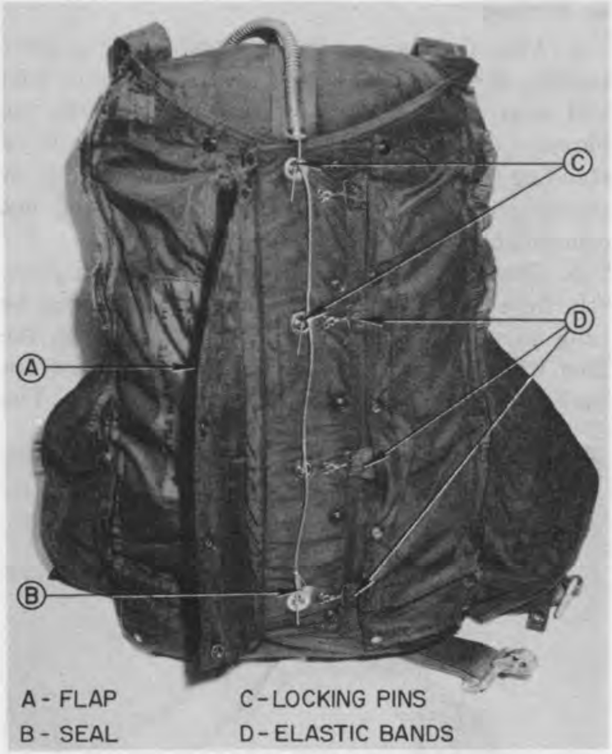


Figure 52. Back of parachute.

Figure 51. Front of parachute.

c. Check for presence of rip cord handle (A, fig. 51) and be sure it will stay in the pocket provided for it. The ripcord (a small metal cable, B, fig. 51) extends through a hole in the handle and should have a metal ball on the end of it. If the ball is not present, the handle will slip off the rip cord instead of extracting it.

d. Check the quick release buckles (C, fig. 51), being sure they work freely and fasten securely. These buckles provide a fast method of separating you from the chute if you should land in water or if the wind starts dragging you when you reach the ground.

e. Check the rip cord on the pack by opening the flap (A, fig. 52) covering it. At the end of the cord, there should be a seal (B, fig. 52), which is a small thread fastened around the cord and the bottom locking cone. If the thread is broken, refuse the chute and obtain another. Inspect each individual locking pin (C, fig. 52). If one of these pins is bent, it could prevent opening of the chute pack by not allowing the rip cord to be extracted.

f. Check the elastic bands (D, fig. 52) for serviceability. These bands aid in pulling the cover of the pack open to allow the canopy to come out more freely.

4. Fitting

a. After determining that the parachute is serviceable, it should be fitted to the individual who will wear it. When all buckles are fastened, the harness should be slightly uncomfortable in a standing position (fig. 53). In a squatting or sitting position, the harness should be snug but comfortable.

b. Chest and leg straps should be adjusted properly for safety reasons. The chest strap should be snug to preclude the buckle slapping you in the face when the chute opens. The shoulder straps each have two adjustments. See figure 53. The front straps have numbers on them and normally can be adjusted to the number that fits your body. However, if the rear straps have been adjusted abnormally before you receive the parachute, they will also require adjusting. The back straps are easily adjusted and permit the user to make a last minute, quick adjustment before bail out. The tighter the harness fits, the less the chance of receiving injuries from the opening shock.

c. Proper fitting is required for comfort when flying and for safety when bailing out.

Note. Because of the maneuverability and short field performance of airplanes used in Army Aviation, it normally is considered as safe to execute a forced landing as to bail out. However, there will be times when it is safer to bail out, such as engine failure during night or weather flying, structural failure, or a major fire. If an emergency should develop requiring a bail out, make the decision to do so and stick to it.

Figure 53. Fitting a parachute.

5. Bail-Out Precautions

After it has been decided to bail out, certain precautions should be taken to minimize the possibility of injury. Ability to take precautionary measures will vary, of course, with the time available for bail out and with the degree of flight control. If the airplane is not controllable, exit must be accomplished in the best way the situation will allow. Try to push yourself clear of the airplane and be sure you actually are clear before pulling the rip cord. The following precautions should be observed to the extent practicable:

a. Slow and trim the airplane as much as possible.

b. Tighten the parachute harness.

c. Remove headset.

d. Jettison the door.

e. Release safety belt and shoulder harness.

f. Dive outward and rearward, being careful to avoid catching the parachute pack on anything as you leave the cockpit.

g. When completely clear of the airplane, firmly pull the rip cord, being sure the cord clears the housing completely.

6. Opening Shock and Descent Precautions

A few precautions can be observed to lessen the opening shock and make the descent as uneventful as possible. These precautions are as follows:

a. Keep your feet together and bend the head forward, putting your chin hard on your chest. This will prevent or lessen injuries which might be inflicted by the opening shock.

b. After the canopy has opened look up at it. If any of the suspension lines are twisted or across the canopy, manipulate the lines by pulling in an effort to correct the fault.

c. Oscillation during descent is quite normal. Observe drift as quickly as possible, then try to turn to face the direction of drift (fig. 54). It will then be possible to see the terrain that will be landed on.

Figure 54. Turning during descent.

d. It is possible to control to some extent the direction of descent by slipping the chute. To slip the chute, pull the suspension lines on the left or right, as appropriate, to cause slipping in that direction. Slipping the chute should be employed only to miss trees, power lines, or water—if the occasion allows. It should not be attempted near the ground.

e. As the ground is approached for landing, look toward the horizon. Never try to land by looking directly below. Employ the same principle as when landing an airplane, looking out and ahead to get better judgment of the rate of fall and nearness to the ground. Keep the feet together, toes pointed down, and hands on the risers.

f. Absorb the initial impact on the toes, then heels, and then start a fall to the side to allow the rest of the impact to be absorbed by the calf of the leg, hip, and shoulder. In the event there is a high wind, open the canopy quick-release buckles after contacting the ground. This will prevent being dragged across the ground. If the releases malfunction, try to get up and run around behind the canopy. If one release functions, the canopy will spill itself but it may drag you a short distance before it does.

g. Should it be impossible to miss trees or foilage during descent, keep the legs crossed and tight together, covering the face with the arms before entering the trees. See figure 55. Be sure a safe climb down can be made before slipping out of the harness.

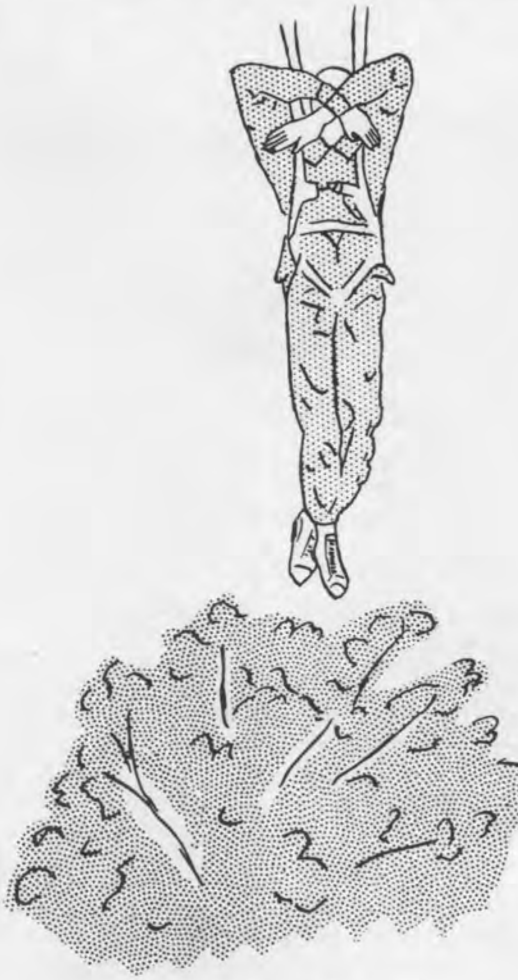


Figure 55. Descent into trees.

h. If it is necessary to land in water, open the canopy quick-release buckles upon touching the water; then start swimming upwind to prevent entanglement in canopy and suspension lines.

7. Parachute Care

An Army aviator has a parachute as a safety precaution. Without proper care, it ceases to provide the safety it should and can. Some points to observe in caring for a parachute are as follows:

a. Never leave the parachute where it may be exposed to rain or dew.

b. Do not let the parachute come in contact with any acid, oil, gasoline, or other substance which might tend to weaken or rot the harness or canopy.

c. Do not leave the parachute on its back; lay it on its harness, to prevent bending the locking pins.

d. Handle the parachute carefully to prevent possible disarrangement of the pack which might keep it from opening properly.

e. If anything happens to the parachute which might cause a malfunction, report it promptly so that corrective action can be taken.

f. Treat the parachute with care and respect: It may save a life.

GLOSSARY

Aileron—A hinged control surface on the wing to aid in producing a bank or roll about the longitudinal axis.

Aircraft—Any form of flying machine.

Airfoil—A portion of an airplane which, when moved through the air, is capable of producing a useful aerodynamic reaction.

Airplane—A mechanically driven, heavier than air, flying machine that derives its lift from fixed wings.

Airspeed—The speed of an aircraft in relation to the air through which it is passing.

Altitude—The elevation of an aircraft above a given reference plane.

Angle of Attack—The acute angle between the chord of an airfoil and its direction of motion relative to the air.

Attitude—The position of an aircraft considering the inclination of its axes in relation to the horizontal.

Axis—The theoretical line extending through the center of gravity of an aircraft in each major plane: fore and aft, crosswise, and up and down. These are the longitudinal, lateral, and vertical axes.

Bank—To tip or roll about the longitudinal axis of the airplane. Banks are essential to all properly executed turns.

Buffeting—The beating effect of the disturbed airstream on an airplane's structure during flight.

Camber—The distance in the curve of an airfoil section from its chord.

Ceiling (Aircraft)—The maximum altitude the aircraft is capable of obtaining under standard conditions.

Center of Gravity—The point within an aircraft through which, for balance purposes, the total force of gravity is considered to act.

Chord—The longitudinal dimension of an airfoil section, measured from the leading to trailing edge.

Controls—The devices used by a pilot in operating an aircraft.

Control Surfaces—Hinged airfoils exposed to the airflow which control the attitude of the airplane and which are actuated by use of the controls in the airplane.

Coordination—The movement or use of two or more controls in their proper relationship to obtain the desired results.

Cruise Control—The procedure for the operation of an aircraft and its power plants to obtain the maximum efficiency on extended flights.

Cushioning Effect—The temporary gain in lift during a landing due to the compression of air between the wings of an airplane and the ground.

Dihedral—The upward inclination of a wing from center section toward the tip.

Dive—A steep descent with or without power at a greater airspeed than that normal to level flight.

Drag—Force opposing the motion of the aircraft through the air.

Drift—Deflection (due to wind) of an aircraft from its intended course.

Elevator—A movable, horizontal control surface used to control the pitch of an airplane.

Empennage—The entire tail group of an airplane, including the fixed and moveable tail surfaces.

Fin—A fixed airfoil which aids directional stability.

Flap—An appendage to an airfoil (usually the wing) used for changing lift and/or drag characteristics.

Flight Path—The path of the center of gravity of an airplane with reference to the earth.

Fuselage—The body to which the wings, landing gear, and tail are attached.

Glide—Sustained forward flight in which speed is maintained only by the loss of altitude.

Glide Angle—The acute angle between the horizontal and downward path along which an airplane descends.

Ground Loop—An uncontrollable violent turn on the ground.

Incidence, Angle of—The angle between the mean chord of the wing and the longitudinal axis of the airplane.

Induced Drag—Drag produced indirectly by the effect of induced lift.

Induced Lift—Lift caused by the low pressure of the rapidly-flowing air over the top of an airfoil.

Kinesthesia—The sense which detects and estimates motion without reference to vision or hearing.

Landing—The act of terminating flight and bringing the airplane to rest.

Landing Gear—The structure which supports the weight of the airplane while at rest.

Leading Edge—The forward edge of any airfoil.

Lift—The supporting force induced by the dynamic reaction of air against the airfoil.

Lift Component—A force acting on an airfoil, perpendicular to the direction of its motion through the air.

Load—The forces acting on a structure. These may be static (as with gravity) or dynamic (as with centrifugal force) or a combination of static and dynamic.

Load Factor—The sum of the loads on a structure, including the static and dynamic loads, expressed in units of G, or one gravity.

Longeron—The principal longitudinal structural member in a fuselage.

Maneuver—Any planned motion of an aircraft in the air or on the ground.

Monocoque—A type of aircraft construction in which the external skin constitutes the primary structure.

Nose Wheel—A turnable or steerable wheel mounted forward in tricycle geared airplanes.

Orientation—The act of fixing position or attitude by visual or other reference.

Overshoot—To fly beyond a designated area or mark.

Pilot—A person trained to operate the controls of an airplane in flight.

Pitch (Airplane)—Angular displacement about the lateral axis.

Pitch (Propeller)—The angle of propeller blades measured from the plane of rotation.

Propeller—A device for producing thrust in a fluid, such as water or air.

Pusher—An airplane in which the engine and propeller are mounted facing aft.

Pylon—A prominent mark or point on the ground used as a fix in precision maneuvers.

Relative Wind—The motion of the air relative to the airfoil; it is parallel and opposite the flight path.

Roll—Displacement around the longitudinal axis of an aircraft.

Roundout—A change of aircraft attitude and flight path from that used on final approach to that used for landing.

Rudder—A hinged, vertical control surface used to control movement about the vertical axis.

Rudder Pedals—Controls within the airplane by means of which the rudder is actuated.

Runway—A strip, either paved or improved, on which takeoffs and landings are effected.

Skid—Sideward motion of an airplane in flight produced by centrifugal force.

Slip—A combination of forward and sideward movement (with respect to the longitudinal axis of the airplane), the lateral axis being included and sideward movement being toward the low end of this axis.

Slipstream—The current of air driven astern by the propeller.

Spin—A prolonged stall in which an airplane rotates about its center of gravity while it descends, usually with its nose well down.

Spiral—A prolonged gliding turn during which at least a 360° change of direction is effected.

Stability—The tendency of an airplane to remain at the same attitude with respect to the relative wind.

Stabilizer—The fixed airfoil of an aircraft used to increase stability; usually, the aft fixed horizontal surface to which the elevators are hinged. Some aircraft have been designed with a moveable horizontal stabilizer.

Stall—A condition of an airfoil in which it is at an angle of attack greater than the angle of attack of maximum lift.

Tail Wheel—A turnable or steerable wheel mounted at the aft end of the airframe.

Taxi—To operate an airplane under its own power on the ground, except that movement incident to actual takeoff and landing.

Terminal Velocity—The hypothetical maximum speed which could be obtained in a prolonged vertical dive.

Thrust—The forward force on an airplane in the air provided by the engine acting through a propeller in conventional airplanes.

Torque—Any turning or twisting force. Applied to the rolling force imposed on an airplane by the engine in turning the propeller.

Trailing Edge—The rearmost edge of an airfoil.

Useful Load—The difference, in pounds, between the empty weight and maximum authorized gross weight of an aircraft.

Vector—A measurement which has both magnitude and direction.

Venturi or Venturi Tube—A short tube having a large opening in the front and rear with a smaller diameter neck in between. The flow through the venturi causes a pressure drop in the smallest section, the amount of the drop being a function of the velocity of flow.

Wash—Air which has been disturbed by the passage of an airfoil.

Wash-in—A greater angle of incidence (and attack) in one wing, or part of a wing, to provide more lift; usually used to overcome torque.

Washout—A lesser angle of incidence to decrease lift. (See wash-in.)

Weathervane—The tendency of an airplane on the ground to face into the wind, due to wind effect on the vertical surfaces of the tail group.

Wing—An airfoil which produces the major portion of the lift of an aircraft.

Wing Root—The end of the wing which joins the fuselage or opposite wing.

Wing Tip—The end of the wing farthest from the fuselage or cabin.

Yaw—To turn about the vertical axis.

Zoom—To climb for a short time at an angle greater than the normal angle, the airplane being carried by momentum.

INDEX

[AG 373.5 (12 Aug 57)]

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Technical Stf, DA
Technical Stf Bd
USCONARC
US ARADCOM
OS Maj Comd
MDW
Armies
Corps
Div
Brig
Regt/Gp
USMA
USA War College
CGSC
Br Svc S h
PMST Sr Div Units
PMST Jr Div Units
PMST Mil Sch Div Units

Mil Dist
Mil Mis
Units org under fol TOE:

5–15	11–25
5–35	11–95
5–225	11–557
5–415	17–35
6–100	17–45
6–135	17–51
6–200	17–55
6–225	29–500
6–235	44–75
6–315	44–275
6–325	51–1
6–415	51–2
6–435	52–2
6–515	55–56
6–535	55–57
6–576	55–87
7–11	55–456
7–31	55–457
11–7	55–458
11–15	57–1

NG: State AG; units—same as Active Army.

USAR: Same as Active Army.

For explanation of abbreviations used, see AR 320–50.

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