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FACTS OF FLIGHT

FEDERAL AVIATION AGENCY

FACTS OF FLIGHT

Practical Information About Operation of Private Aircraft

Revised May 1963

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Introductory Note

This booklet will not teach you how to fly, how to overhaul an engine, or how to repair an airplane. Rather, its purpose is to increase your pleasure and safety in flying by explaining, briefly and simply, some important facts that have been learned through pilot experience, engineering research, and accident analysis.

The material available in this field is so extensive that only the essentials can be included here. Accordingly, the topics selected for discussion have been restricted to those which will help you to fly with greater skill and confidence, to avoid unnecessary expense, and to gain the greatest satisfaction from your flight experiences.

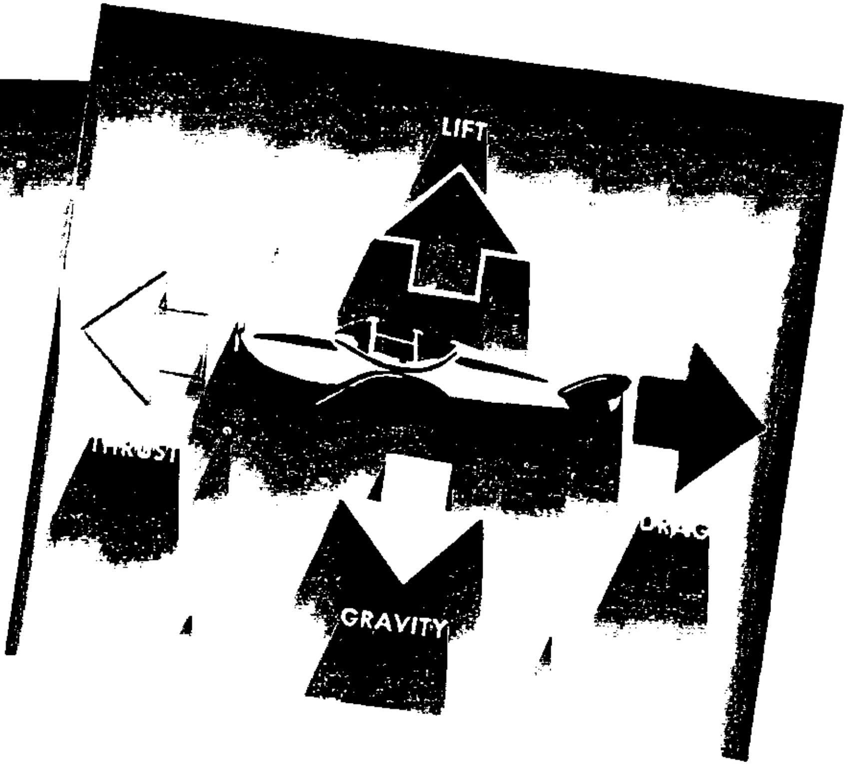
This publication must not be regarded as a substitute for a competent flight instructor. It does, however, explain in some detail many of the reasons for your instructor's emphasis upon certain procedures and techniques in flight. Also, by stating fundamentals in nontechnical terms, it may serve as a valuable supplement to the practical instruction which only your flight instructor is competent to supply.

FACTS OF FLIGHT is the third of a series of short manuals prepared by the Flight Standards Service of the Federal Aviation Agency, to provide the private pilot with information essential to the safe operation of his aircraft.

The first of this series was REALM OF FLIGHT, a presentation of practical information about the effect of atmospheric conditions upon flight. The second was PATH OF FLIGHT, providing the private pilot with information essential to the safe navigation of his aircraft.

Table of Contents

Airplane Flight



A pilot, to be skillful, must have more than an elementary knowledge of how to move the controls. He must have an adequate concept of the forces which act upon his airplane, the way in which these forces may be most advantageously used, and the limitations of his airplane.

To have complete mastery of his airplane, the pilot must understand why an airplane flies and how his application of the various controls affects its flight. Equipped with that understanding, he is able to fly within safe limits, to avoid dangerous practices, and to deal correctly with unexpected or unusual situations.

Atmospheric Pressure and Lift

The force which makes flight possible is atmospheric pressure acting upon the wings of the airplane. The force available from atmospheric pressure is far greater than is generally realized. Air is one of the lightest substances known; but, because of its immense mass extending to a height of more than 200 miles, it exerts a pressure at the earth's surface of approximately 1 ton per square foot. Normally this pressure is fairly well equalized, or in a state of balance. Consequently, it is scarcely noticeable.

Whenever the balance is disturbed, however, air will attempt to move from areas of higher pressure toward areas of lower pressure and, in so doing, will exert tremendous force. Its power under such conditions becomes evident in windstorms, tornadoes, and hurricanes. The very same source of energy makes flight possible by exerting force upon the wings of an airplane.

When the wing is stationary the downward pressure of air upon its upper surface is equalized by the upward pressure upon its under surface, and the forces are balanced. (See fig. 1.) When the wing moves forward, however, it disturbs this balance by creating a low-pressure area above its upper surface. The air below the wing, therefore, having a normal, or slightly higher-than-normal pressure tries to move upward into the low-pressure area. The wing, however, lies between these two areas; consequently, an upward pressure is exerted upon the wing. This force is called "lift." (See fig. 2.)

The Source of Lift

The lift which supports an airplane in flight is sometimes explained as a force developed by the impact of air upon the under surface of the wing, like the planing effect of a surfboard or speedboat skimming over the water. Such an explanation is somewhat misleading. To a limited extent the impact of air beneath the wing contributes to the total lift, but the primary source of lift is reduction in pressure above the wing rather than increase in pressure below. In fact, when the wing is flown at such an angle that it receives no support whatever from impact, it can develop adequate lift to support an airplane.

A detailed discussion of the mechanical forces which produce the low-pressure area above the wing would be of little practical value to the pilot, and therefore is omitted. It is important, however, for the pilot to know that lift is derived from this source rather than from impact, if he is to understand the reason for stalls and spins which will be discussed in the next chapter.

To develop enough lift to support an airplane the wing must move rapidly through the air, propelled by the thrust or pulling force of the propeller. The faster the wing moves, the more lift it can develop. A light plane weighing 1,500 pounds may require a speed of 40 m. p. h.[1] to gain enough lift for flight. Faster and heavier planes may require much greater speeds. Speed necessary for flight is not primarily dependent, however, on size and weight of the airplane, but on wing design and total weight of the airplane in relation to total wing area.

As the airplane moves forward in flight, there arises a relationship between the moving airplane and the air, which is called "relative wind." Actually this is not wind in the usual sense; it is not air in motion. It is the effect of the air's resistance to a moving object, very noticeable in a roller-coaster ride. The "wind" seems always to blow in the riders' faces, whether the car is going up or down, or turning to one side or the other. In an airplane, the direction of the relative wind is determined by the flight path. (See fig. 3.)

Angle of Attack

As the airplane moves along its flight path, the wing is inclined so that its chord (a hypothetical line running approximately parallel to the flat under-surface of the wing) meets the relative wind at a slight angle, called the "angle of attack." (See fig. 5.) At any given airspeed, this angle of attack determines the amount of lift which the wing will develop. At small angles the lift is at a minimum; as the angle is

Figure 1. When a plane is on the ground, atmospheric pressures (indicated by arrows) above and below the wing are equal.

Figure 2. In flight, forward motion of the wing produces a low-pressure area (red). Thus pressure above the wing is less than below it.

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[1] Because speeds often are expressed in "knots," the private pilot should become familiar with the use of that term.

Figure 3. "Relative wind" is not "air in motion." The resistance of air gives the effect of wind rushing past a moving object. Whether the moving object is in the air or on the ground, going "uphill" or "downhill," the relative wind always comes from directly ahead.

increased, the lift is also increased. There is, however, a limit beyond which an increase in angle ceases to produce an increase in lift. For most airplanes this maximum effective angle is about 20 degrees. An increase beyond the maximum angle (sometimes called "stalling angle") produces a turbulent condition in the air above the upper wing surface, reducing effectiveness of the low-pressure area above the wing, and thereby causing a substantial loss in lift. This condition leads to stalls and spins, which will be discussed more fully in the next chapter.

The angle of attack, since it is a relationship between the attitude of the wing and the relative wind, cannot be measured as the angle of the wing with reference to the ground, but must be measured as the angle between the wing and the flight path. (See fig. 6.)

The air resistance constitutes a retarding force which tends to impede the forward motion of the airplane. This force is called "drag." When the wing is flown at small angles of attack, the drag on the wing is at a minimum. As the angle is increased, drag increases very rapidly, and at high angles of attack, drag becomes a very significant factor. Drag also increases with increase in air speed. To obtain maximum performance from his airplane, the pilot must know how to control the air speed so as to secure the most efficient relationship between the forces of lift and drag. Practical suggestions on this subject are offered in the chapter entitled "Flying the Plane."

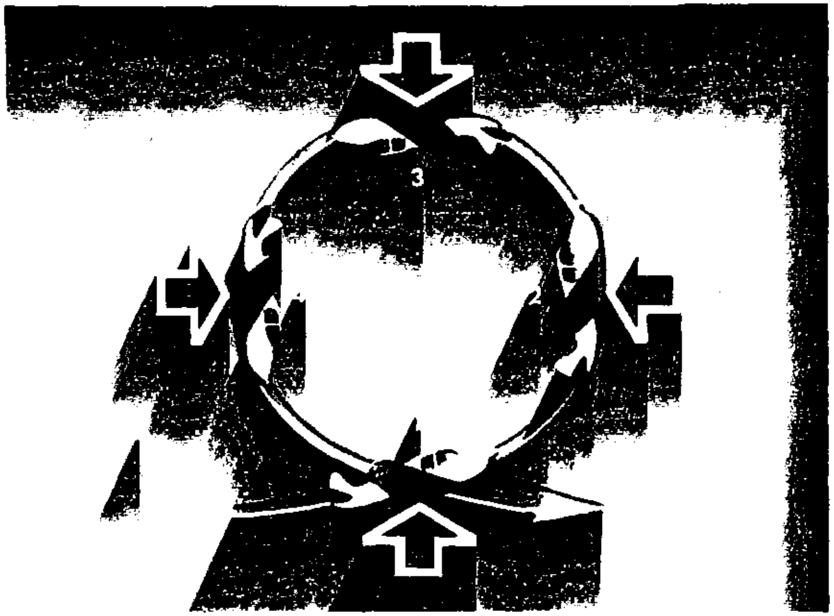

Figure 4. Lift (arrows) always is exerted at right angles to the flight path (red) and is not necessarily opposed to gravity. When a plane begins a "loop" (stage 1), the lift is upward. It is sidewise at stage 2, downward at stage 3, and sidewise again at stage 4.

Direction of Lift

When an airplane is flown so that the wings are level, the lifting force is directly upward, opposed to gravity. However, as has already been pointed out, lift is an "upward" force on the wing itself, and is

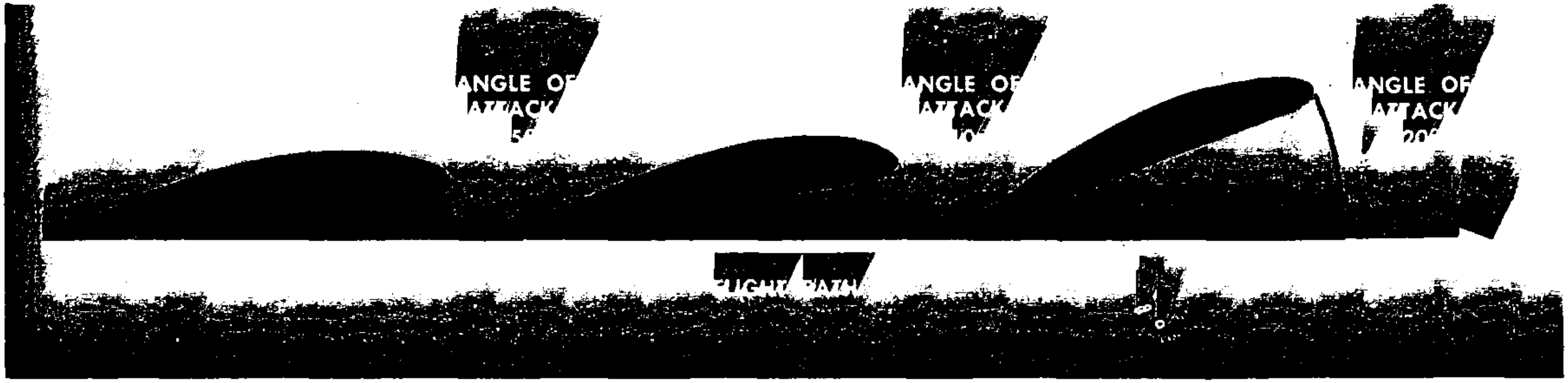

Figure 5. Angle of attack (red) is angle between flight path and wing, shown in profile (black). Three variations of the angle are depicted.

not necessarily related to gravity. Consequently, if the airplane is banked in a turn, or is in a steep climb or dive, the lift exerted on the wing will not necessarily be "upward" with reference to the ground. For example, in a loop, the lift is constantly exerted toward the center of the circle. At the start of the loop this force is upward from the ground. When the plane is flying straight up, the lift is parallel to the ground. At the top of the loop, the lift is exerted toward the ground. Coming straight down, lift is again parallel to the ground. (See fig. 4.)

These changes in direction of lift can be very confusing if we conceive of lift as being a force always acting upward with relation to the ground. However, we will have no difficulty if we regard lift as a force which always acts at right angles to the flight path.

Functions of the Controls

An airplane, like any moving object, tends to continue in a straight line unless some force is applied to change its direction. The direction of flight is governed by a set of controls consisting basically of the throttle, the elevators, the rudder, and the ailerons. (See fig. 7.)

Throttle

The throttle governs the output of power needed for flight. Opening the throttle increases the energy available for gaining altitude, for increasing forward speed, or for executing manuevers.

Elevator

The elevator is a horizontal hinged surface attached to the tail. Its function is to control the angle of attack—the angle at which the wings move forward along the flight path. When the pilot applies back pressure on the control stick or control column, the elevator is tilted upward. The relative wind, striking the elevator on its upper surface, forces the tail down. This changes the angle of the wings in relation to the flight path, increasing the angle of attack. Forward pressure on the control stick tilts the elevator downward, raises the tail, and thus reduces the angle of attack.

Some pilots have the misconception that movement of the elevator causes the airplane to gain or lose altitude. This concept is entirely inadequate; in fact it is positively dangerous, and is undoubtedly responsible for a large number of fatal accidents.

Under certain flight conditions it is true that an airplane will climb when the elevator is raised and dive when it is lowered. But under other conditions of flight, raising the elevator will not result in an increase of altitude. For example, when an airplane is descending preparatory to landing the elevator must be tilted upward, not to increase

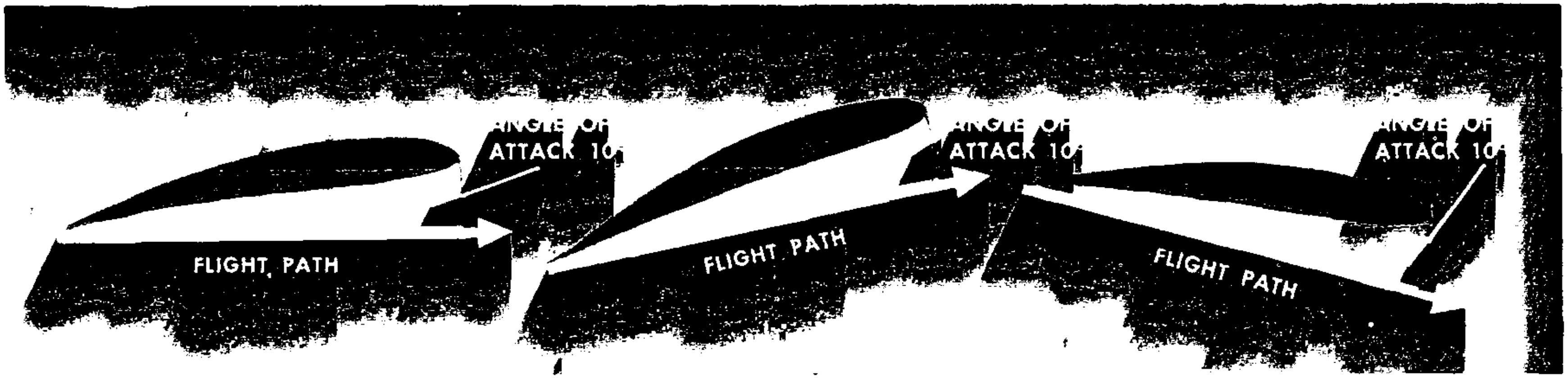

Figure 6. The angle of attack (red) always is based upon the flight path, not the ground. The illustration shows how the angle of attack can remain constant even though the angle with reference to the ground is changed.

altitude, but to maintain altitude or to lose altitude less rapidly. In a stall, if the control is held all the way back with elevator in full "up" position, the airplane will continue to descend rapidly until it strikes the ground. For the greatest safety in flight it is better for the pilot to think of the throttle as an altitude control, and the elevator as merely a device to govern the angle of attack.

Rudder

The rudder is a vertical surface hinged to the tail and generally operated by foot pedals. Its function is to swing the tail to the left or right, just as the elevator forces the tail up or down. The proper use of the rudder is often confusing to beginners. *On the ground* it is used to make the airplane turn, like the rudder on a boat or the steering wheel of an automobile. *In flight,* however, its primary function is not to *make* the airplane turn, but to assist it in entering and recovering from turns and to make minor adjustments for directional control or to execute maneuvers involving abnormal attitudes of the airplane. The rudder is perhaps the most frequently misused control on the airplane. When properly applied it is a valuable aid to precision flying, but its misapplication during a turn may lead to dangerous slips, skids, stalls, and spins.

Ailerons

Turns in flight are accomplished by tilting the wing through the use of ailerons. To enter and recover from turns, use of the rudder is coordinated with movement of the ailerons. Ailerons are small sections of the trailing edge near the wing tips, which are hinged and so connected that a sidewise movement of the control stick, or turning of the control wheel will lower one aileron and raise the other simultaneously. If the control stick is moved to the left, while the airplane is flying level, the left aileron will tilt upward, reducing the lift, and the right aileron will move downward, increasing the lift. In consequence, the right wing will rise, and the plane will be tilted or banked to the left. The total lifting force of the wing will then no longer be exerted vertically upward, but will be pulling the airplane somewhat to the left, producing a left turn. Phrasing it in another way, the airplane is "lifted" around the turn.

Flaps

All but the smallest airplanes are equipped with flaps, which are attached to the trailing edges of the wings, between the ailerons and the fuselage. These serve to change the lifting capacity of the wing by changing the shape or area of the wing surface. An increased lifting capacity permits slower landing and take-off speed. On the other hand, increased lift causes greater drag, with consequent loss in top speed. By lowering the flaps the pilot gains the advantage of high lift at low speed; by retracting them he reduces the drag at high speed.

An airplane in flight is constantly subjected to four forces—thrust, drag, lift, and gravity. Thrust, the forward pull of the propeller, is opposed to drag, the retarding force which resists forward motion. Lift, the upward force on the wings is normally opposed to gravity. By the use of the controls on the airplane, the pilot governs the relative effectiveness of each of these four forces, and thus is able to execute maneuvers and to exert complete mastery over his airplane.

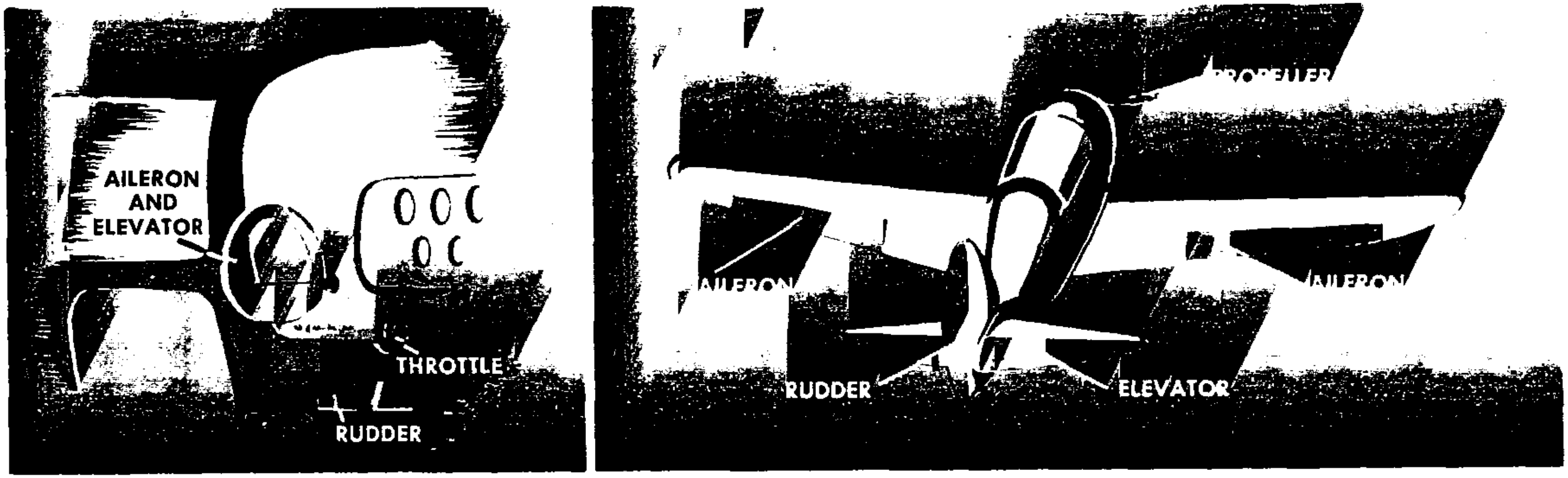

Figure 7. Conventional arrangement of controls (red) is shown at left. Plane's surfaces which respond to the controls (red) are shown at right.

Stalls and Spins

Accidents attributed to stalls and spins have created a general misconception regarding these maneuvers. Stalls and spins are not eccentricities of flight, but are normal reactions of the airplane to the pilot's use of controls. Left to its own resources, an airplane will avoid these maneuvers or, if forced into them, will recover of its own accord. Unintentional stalls and spins occur only when an airplane is mishandled and made to violate its normal tendencies.

When an airplane stalls, the wings lose lifting power, the controls lose effectiveness, the nose drops, and the airplane falls rapidly toward the ground. If the airplane rotates during the descent, the stall becomes a spin.

The Cause of Stalls

The loss of lift which produces a stall is caused by an excessive angle of attack. For most airplanes, the maximum effective angle of attack is about 20 degrees. If, then, the pilot, by back pressure on the elevator control, forces the wings to exceed this angle, the low-pressure area above the wing which produces most of the lifting force will be destroyed by the turbulent eddies. Then the airplane, losing much of its supporting force, will stall.

Most pilots associate stalls with slow air speed. Generally there is a close relationship between the two, but pilots should know that an airplane can stall at any speed from its minimum to its maximum. The controlling factor is the angle of attack, and not the air speed. Stalls occurring at relatively high speeds are likely to be more dangerous because they may be unexpected and are more violent.

Figure 8 will make clear what happens when an airplane stalls.

Stage 1 shows an airplane in normal level flight at an angle of attack of about 5 degrees.

When the throttle is closed (Stage 2), if no back pressure is applied to the elevator control, the nose will begin to drop and the wings will maintain their angle of attack at about 5 degrees with reference to the descending flight path.

If the pilot now applies back pressure on the elevator control in an attempt to hold the airplane in a level attitude, speed drops and the angle between the wings and the descending flight path will rapidly increase, reaching the stalling angle, as shown in Stage 3.

When the stalling angle is reached, burbling or turbulence of the air above the wing destroys much of the lift. The airplane then ceases to fly, and drops rapidly toward the earth (Stage 4). If at this point the pilot continues to hold back pressure on the elevator control, the wings will be forced to maintain an excessive angle of attack with reference to the downward path, and the airplane will continue to fall until it strikes the ground.

If, however, the pilot releases back pressure, the nose will drop quickly, permitting the wings to reestablish a normal angle of attack on the downward path (Stage 5). The airplane will attain flying speed along its downward path, lift will be regained, and the pilot can gradually return to normal level flight (Stages 6 and 7).

If, during the recovery to level flight, the pilot applies too much back pressure on the elevator control, he may again increase the angle of attack too greatly and force the airplane into a second, or "progressive," stall.

Detecting Stall Conditions

Excessive angle of attack is the only cause of stalls. Many airplanes are now equipped with stall-warning devices which warn the pilot of an approaching stall.

In airplanes which are not equipped with stall-warning devices, the most dependable instrument for detecting an approaching stall is the airspeed indicator. Except in the case of stalls caused by high load factors due to steep turns and abrupt pull-ups, there is a definite relationship between air speed and stalling conditions. In fact, every good pilot, when flying an airplane with which he is unfamiliar, will climb to sufficient altitude and learn the stalling characteristics of the plane in relationship to the indicated air speed. The procedure is exactly as shown in figure 8 illustrating the mechanics of a stall. At the moment the stall occurs (Stage 3) the pilot will note the indicated air speed. This gives him the exact air speed at which the airplane will stall when he is making his approach for a landing. It is also a basic figure from which he can compute the most efficient speeds for climbs and glides, as well as the increased speeds at which an airplane will stall when executing turns.[1]

Unintentional stalls occur most frequently while turns are being made. This is probably because an airplane will stall at a higher air speed when turning than when in level flight. Stalls from turning flight may give little or no warning, and frequently develop into spins.

When an airplane is banked in a turn, the direction of lift is not vertically upward from the ground, but is inclined toward the horizontal. Thus, the lifting force developed by the wing pulls the plane "sidewise" as well as "upward." If the airplane is to maintain altitude during the turn, the portion of lift exerted vertically must be adequate to support the weight of the plane. Consequently, in a turn, the total lift developed by the wing must be greater than the amount required for straight flight.

The portion of the total lift which pulls the plane sidewise (with reference to the ground) forces the plane to follow a circular path. In so doing, it opposes centrifugal force, the force that tends to make the plane follow a straight path rather than a curve.

Obviously, the minimum air speed required to provide adequate lift to maintain altitude during straight flight is not sufficient to provide enough lift for a turn. The extra lift for turning must be supplied by an increase in air speed. The steeper the bank, the greater the air speed required. This relationship between angle of bank and air speed is such that it is possible to compute the approximate air speed required to prevent stalling in any specific angle of bank.

A method for computing the approximate stalling speed for any airplane during a turn is provided by the following table. Select the figure in column 2 corresponding to the angle of bank in column 1. Multiply that figure by the normal stalling speed of the airplane. The result will be the approximate stalling speed in the turn. Column 3 shows the results of this computation for an airplane which has a normal stalling speed of 50 m. p. h. It should be noted that the stalling speed increases rapidly as the angle of bank approaches

Angle of bank (degrees)	Factor for multiplication	Result based on normal stalling speed of 50 m. p. h.
20	1.03	52
30	1.07	54
40	1.14	57
50	1.25	62
60	1.41	71
70	1.71	85
80	2.40	120

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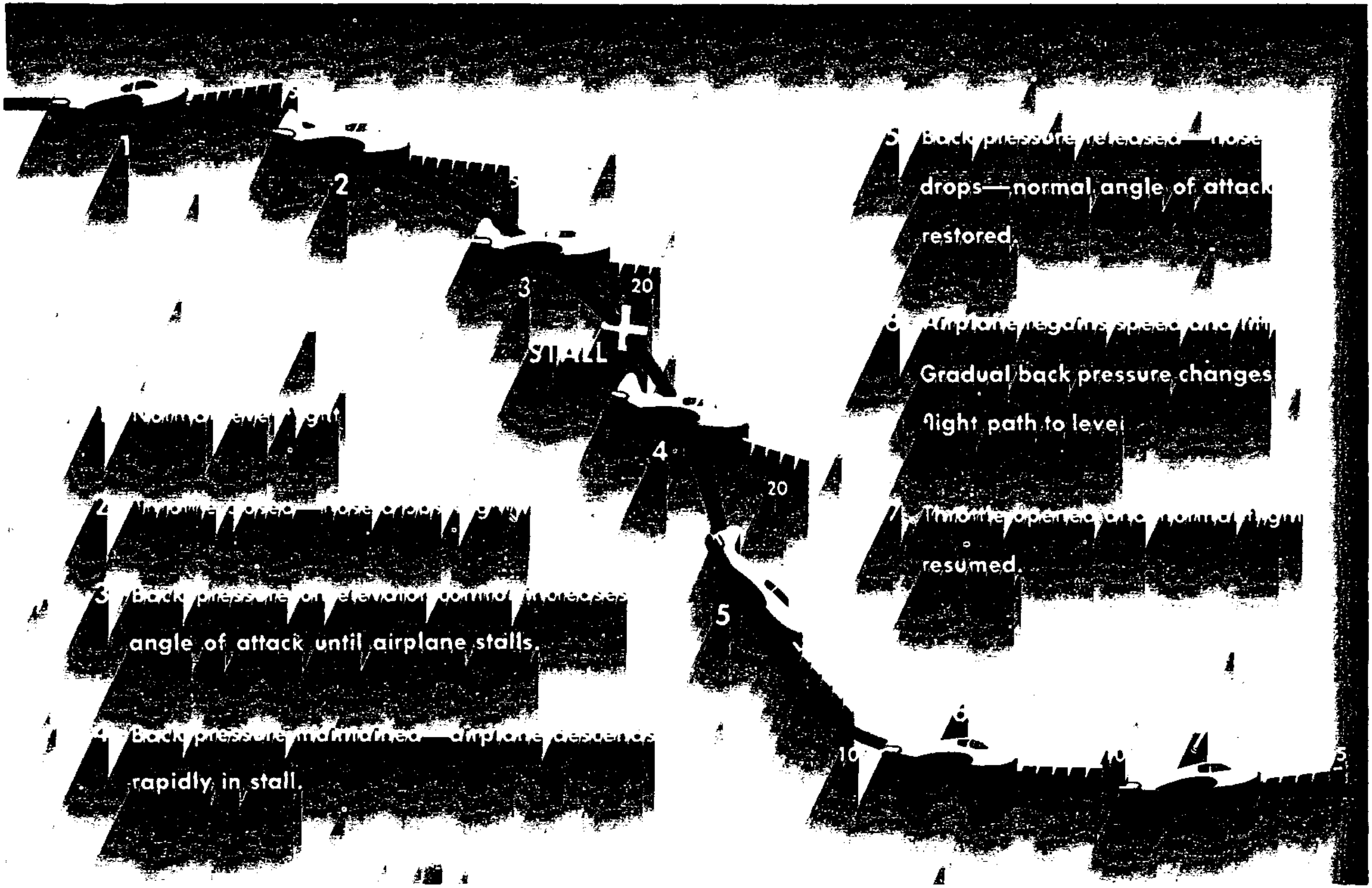
[1] During practice stalls and spins the engine may stop if the throttle is closed completely. To prevent this, the throttle should be only partially closed, and the r. p. m.'s maintained above 800 during the entire maneuver.



1 Normal level flight.

2 Throttle closed—nose drops slightly.

3 Back pressure on elevator control increases angle of attack until airplane stalls.

4 Back pressure maintained—airplane descends rapidly in stall.

5 Back pressure released—nose drops—normal angle of attack restored.

6 Airplane regains speed and fli
Gradual back pressure changes
flight path to level.

7 Throttle opened and normal flight resumed.

Figure 8. This diagram indicates conditions before, during and after a stall. The heavy black line shows the general flight path. The angle of attack at each depicted position of the plane is shown between dotted black line (momentary flight path) and dotted white line (angle of wing).

the vertical. At 90 degrees the lift of the wings is acting horizontally and there is no vertical lift available to maintain altitude in a turn, except momentarily.

The table on page 8 shows the principle of increased stalling speed in turns, but is not entirely dependable as a guide, because pilots are seldom aware of the exact angle of bank. Moreover slips, skids, gusty conditions, or abrupt handling of the controls will produce stalls, even at an air speed presumably above stalling. The pilot should, therefore, supplement knowledge obtained from this air-speed indication by noting the "feel" of the plane: the attitude of the nose, the sound of the engine, the responsiveness of the controls, and especially the amount of back pressure being exerted on the elevator control.

Stall Recovery

Prevention of a stall, or recovery, can always be effected by the simple expedient of releasing back pressure on the elevator control, or moving the stick slightly forward. The addition of power will also be helpful. In a turn, an approaching stall may be averted by leveling the wings. When a stall occurs at low altitude, a pilot must overcome his normal reaction to pull back on the elevator control. He must substitute a trained reaction to reduce angle of attack and increase power immediately. Unfortunately, most inadvertent stalls occur at altitudes too low for recovery with even most skillful handling.

In addition to high-speed stalls, normal stalls, progressive stalls, and stalls in turns, a few other types should be mentioned.

When an airplane is trimmed tail-heavy, preparatory to landing, a sudden application of power will produce a strong blast of air from the propeller, exerting a downward pressure upon the stabilizer and elevator. On some airplanes this pressure will produce a sudden change in attitude, increasing the angle of attack sufficiently to produce an immediate stall. To prevent such a stall, the stick or wheel should be moved forward when power is applied.

Special care should be used in handling flaps on airplanes so equipped.

Figure 9. Use of "bottom rudder" while a plane is banked in a turn may cause a skid toward the outside of the turn.

Figure 10. When a plane banks during a turn, use of "top rudder" may cause a slip toward the inside of the turn.

In "down" position the flaps change the form of the wing in such a way as to increase lift and reduce the speed at which the wing will stall. Consequently, the airplane can be flown safely at slower air speed than would otherwise be possible. When flaps are released to "up" position, the airplane tends to sink because of loss of the added lift. To offset the sinking, the pilot will frequently raise the nose by back pressure on the elevator control to increase the angle of attack. This procedure is satisfactory if the airplane is flying at a speed well above stalling speed. If the speed is critical at the time the flaps are released, however, back pressure to raise the nose may produce an immediate stall.

Stalls sometimes are caused by gusty wind conditions. When an airplane is approaching for a slow-speed landing, flying at almost stalling angle, a momentary change in wind velocity or direction or a variation in the force of vertical currents may be sufficient to cause a stall. The best way to avoid such a stall is to make the approach at a higher speed and, if conditions are severe, to land on the wheels rather than in a three-point attitude. A word of warning is advisable concerning landing, taking off, or flying behind fixed-wing or rotating-wing (helicopters) aircraft. Turbulent air created by the passage of either fixed-wing aircraft or a helicopter through the atmosphere is shed off the wing tips or rotor tips into swirling vortices which, under certain conditions, may extend several miles behind the generating aircraft and may affect a light airplane in much the same way as a sudden gust and can, under extreme conditions, cause structural failure. The most severe turbulence is generated by aircraft operating at slow airspeeds—such as immediately after take-off or just before landing.

Skids and Slips

Skids and slips are primarily caused by abnormal use of the rudder. If "bottom" rudder is held in a turn, the nose of the airplane will swing toward the inside of the turn, but the airplane itself will skid sidewise toward the outside, just as an automobile skids sidewise on a slippery highway. During the skid, the airplane, in this sidewise attitude, is subjected to greater drag, which reduces air speed and causes loss of lift. To maintain altitude, the pilot may instinctively use back pressure on the elevator control, increasing the angle of attack sufficiently to

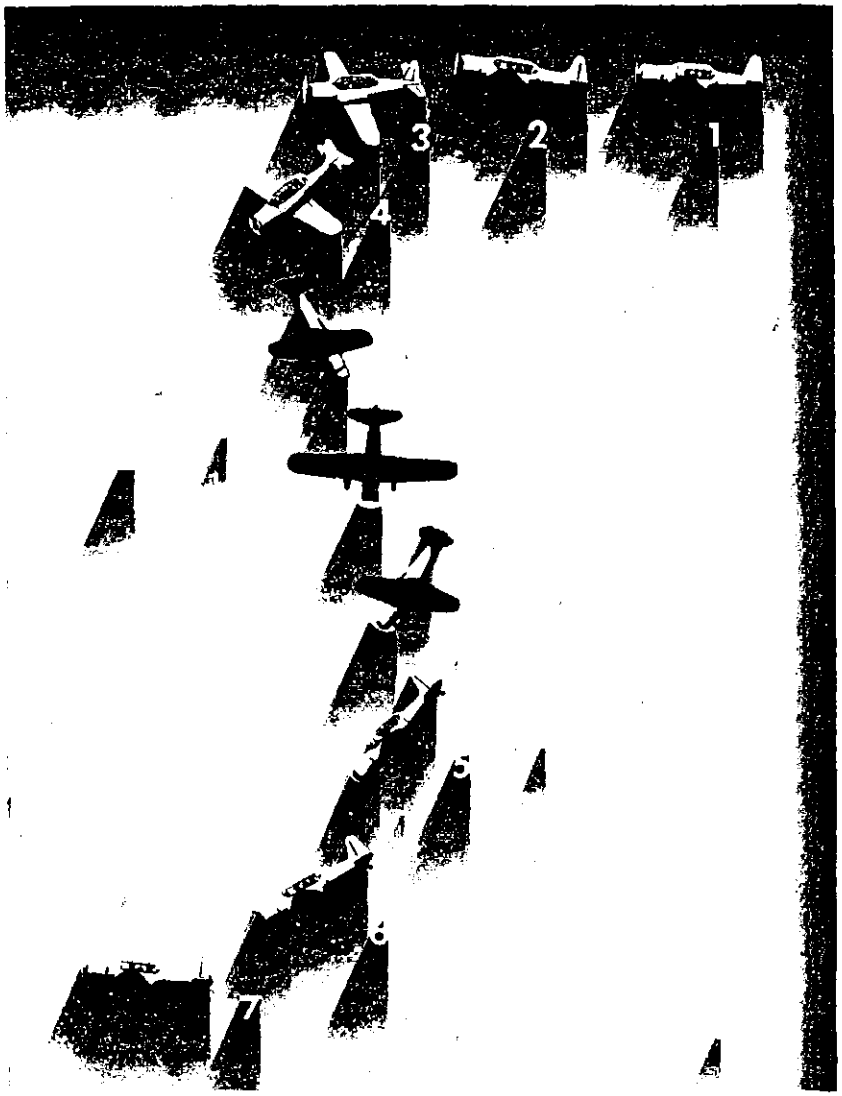


Figure 11. The successive positions of a plane during a one-turn spin. (1) Normal flight. (2) Stall. (3) Left wing drops. (4) Plane begins to spin. (5) Spin ends. (6) Plane begins recovery. (7) Normal flight.

cause a stall, particularly when the airplane is already flying at slow speed in the approach for a landing or in the initial turn after take-off.

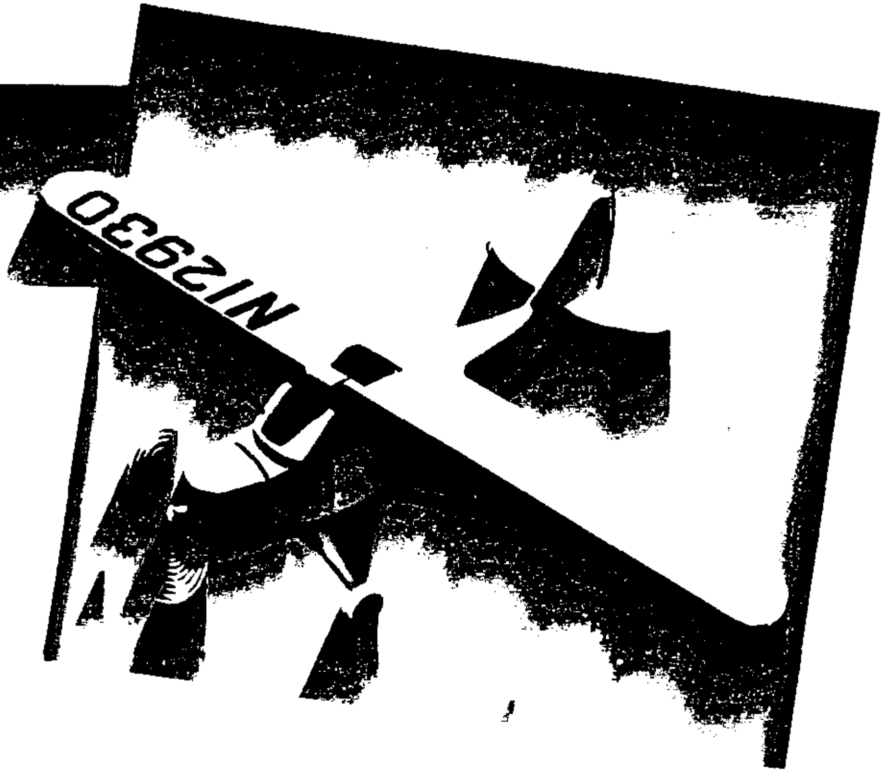
If "top" rudder is held in a turn the nose will swing toward the outside of the turn, but the airplane will slip toward the inside, causing loss of lift in much the same way as a skid. Slips are frequently executed deliberately to lose excess altitude in approaching for a landing. They do not present any real danger of stalling so long as the nose is held low enough to maintain adequate air speed during the slip and in the recovery.

Recovery From Spins

Little has been said in this chapter about spins. Many years ago a spin, or "tailspin" as it was then called, was regarded as an extremely dangerous maneuver because recovery was almost impossible. At present, however, all light airplanes capable of spinning are designed and tested to recover from spins even without the aid of the pilot. The recovery technique generally used is the same as for a stall, except that the rotary motion of the airplane is stopped by the application of opposite rudder before the nose is lowered to restore the normal angle of attack.

This chapter has been devoted to the discussion of stalls and spins because they are the direct cause of 55 percent of the fatal airplane accidents. When executed deliberately at a safe altitude they are not dangerous, but the exact amount of altitude that will be lost cannot always be determined. For that reason, pilots should be particularly cautious when near the ground to avoid any possibility of a stall and subsequent spin. Accident reports record an alarming number of cases in which pilots, while "buzzing" homes of friends, have failed to recognize the approaching stall and have "spun in" from steep turns or zooms. In such instances, no amount of recovery technique could have prevented the inevitable crashes and fatalities.

Airplane Structure



Of the many activities conducted by the Federal Aviation Agency in promoting safety in flight, perhaps none is of greater importance to pilots than certification as to the airworthiness of airplanes. Every airplane certificated under the Standard Classification has been manufactured under rigid specifications as to design, materials, workmanship, construction, and performance.

Thousands of wing designs—they are called "airfoils"—have been developed in an effort to determine the best types for specific purposes. Basically all are similar to those used by the Wright Brothers and other pioneers, but modifications have been made to increase the lifting capacity, reduce friction, increase structural strength, and generally improve flight characteristics. (See fig. 12.) Airfoils of new design are subjected to painstaking analysis before they are approved for use on certificated airplanes. Strength tests are conducted to determine the effect of strains and stresses which might be encountered in flight.

The most minute details of the entire structure of the airplane are given careful consideration—the strength and durability of each individual part, the method of assembling, the weight and balance. Maximums and minimums are established for performance—take-off distance, rate of climb, landing speed, spin recovery characteristics, etc. Before delivery, every new airplane has been subjected to a thorough inspection and has been flight-tested. The Standard Classification gives adequate assurance that the airplane will not be subject to structural failure *if* it is properly maintained, and flown within the limitations clearly specified. It does *not* mean that the airplane is safe if abused, improperly maintained, or flown without regard to its limitations.

The goal of airplane design and construction is to obtain maximum efficiency, combined with adequate strength. Excess strength requires excess weight and therefore lowers the efficiency of the airplane by reducing its speed and the amount of useful load it can carry.

The required structural strength is based upon the use for which the airplane is intended. An airplane which is to be used only for normal flying will not be subjected to the excessive strains which would occur in acrobatic maneuvers, and therefore will not need to be so strong and heavy as an airplane intended for advanced pilot training.

To permit utmost efficiency of construction without sacrificing safety, the FAA has established several categories, with minimum strength requirements for each. Information as to limitations of each airplane is made available to the pilot through markings on instruments, placards on instrument panels, operating limitations attached to airworthiness certificates, or airplane flight manuals carried in the airplane.

An airplane's strength is measured basically by the total load which the wings are capable of carrying without permanent damage. The load imposed upon the wings depends very largely upon the type of flight in which the airplane is engaged. The wings must support not only the weight of the airplane but also the additional loads imposed during maneuvers. In a 60-degree bank (if altitude is maintained) the total lift, and therefore the load on the wing, equals twice the normal weight. A 70-degree bank brings the total load to almost three times the original; an 80-degree bank almost six times. (See fig. 13.)

Similar increases in load may be caused by pull-outs from a dive. In a quick pull-out at high speed, it is possible for a pilot to impose loads far beyond the structural strength of the wings on any airplane. As an extreme example, if an airplane weighing 1,100 pounds were dived at about 200 m. p. h. and pulled out abruptly, the load on the wings—if they were strong enough to hold it—would be 25 times the weight of the airplane—almost 14 tons.

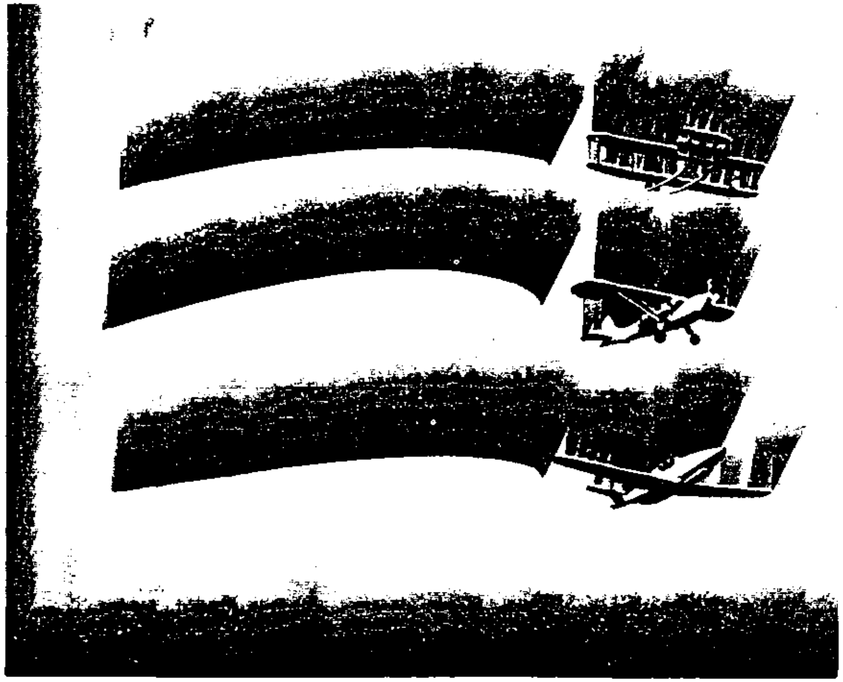


Figure 12. Three types of wings are shown in cross-section. Top: The pioneering design used by the Wright Brothers. Middle: The "high-lift" wing. Bottom: The high-speed wing.

To a lesser degree, rough air imposes additional loads upon the wings. Violent gusts encountered in high-speed flying may produce momentary increase of load equivalent to four or five times normal weight.

Airplanes in categories of interest to the private pilot will withstand the limit-load factors shown in the table which follows. The limit loads should not be exceeded in actual operation, even though a safety factor of 50 percent above limit loads is incorporated in the strength of the airplane.

Category	*Limit load*
Normal (nonacrobatic)	3.8 times gross weight.
Normal (designs which are characteristically incapable of spinning)	3.5 times gross weight.
Utility (normal operations and limited acrobatic maneuvers)	4.4 times gross weight.
Acrobatic	6.0 times gross weight.

Observance of Limitations

Some planes have an accelerometer, which measures the load on wings; but a pilot normally must use other means to determine if he is flying within proper limits. One indication is the feeling of bodily weight. When the load on the wings is increased, the effective weight of the pilot is also increased. In fact, if you were to sit upon a bathroom scale during flight, you would find that it would register your exact weight in level flight, but in a turn with a 60-degree bank it would register double your weight. This added weight can easily be sensed and is a fairly reliable guide to indicate increases up to twice the normal load. As the load approaches three times normal, you will notice a sensation of blood draining from your head, and a tendency of your cheeks to sag. A considerably greater increase in load may cause you to "dim out" or "black out," temporarily losing your vision.

Loads greater than the weight of the airplane are produced by back pressure on the elevator control or by sudden gusts. The amount of excess load which can be imposed on the wing depends upon the speed

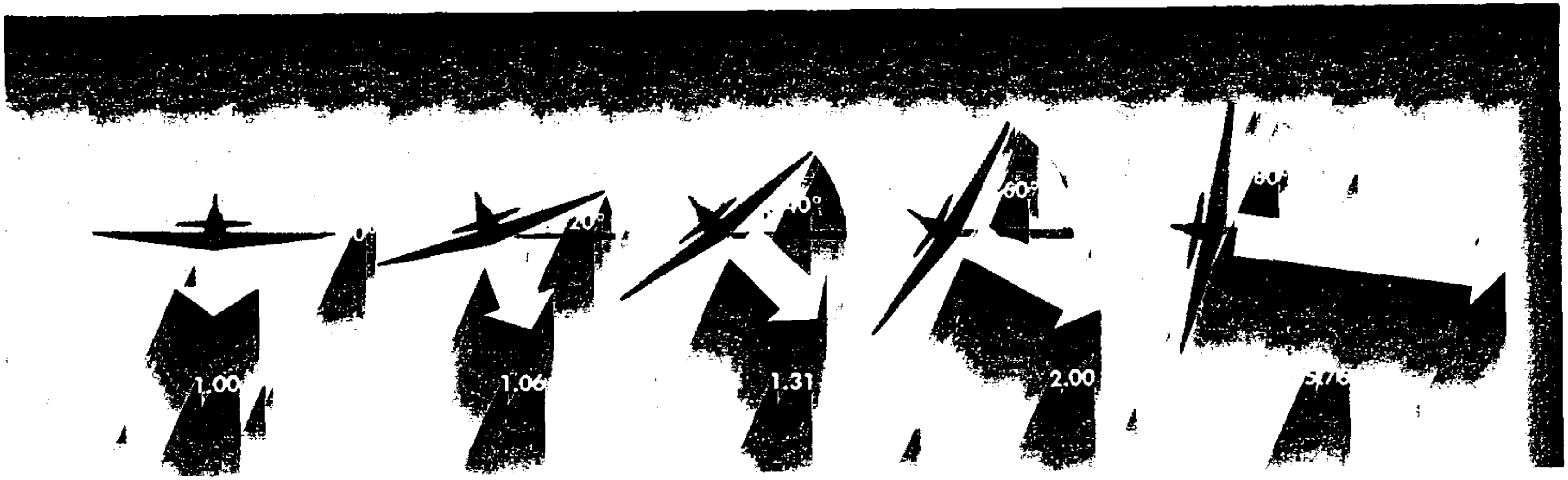


Figure 13. The load on the wings increases when the angle of bank (red) increases. The rate of increase is shown by the length of the white arrows. Figures below the arrows indicate the increase in terms of the plane's weight. For example, the load during a 60-degree bank is shown as 2.00, being twice the weight of the plane in level flight.

at which the airplane is flying. At slow speed the available lifting force of the wing is only slightly greater than the amount necessary to support the weight of the airplane. Consequently, the load cannot become excessive even if the controls are moved abruptly or the airplane encounters severe gusts. At high speed the lifting capacity of the wing is so great that a sudden movement of the controls or a strong gust may increase the load beyond safe limits. Because of this relationship between speed and safety, certain "maximum" speeds have been established, and every airplane is restricted as to the speeds at which it is safe to execute maneuvers and to fly in rough air.

Never-Exceed Speed

The never-exceed speed is the maximum at which the airplane can be operated safely in smooth air. No pilot should ever exceed this speed intentionally; but if the plane should approach the never-exceed speed inadvertently, it should be handled very carefully, and the pull-out made slowly and gently.

Maximum Structural Cruising Speed

The maximum structural cruising speed is the greatest safe speed for gentle maneuvers in moderately rough air. (On some airplane operating limitations this is referred to as "Maximum Cruising Speed," or "Climb or Level Flight Speed.")

Maneuvering Speed

The maneuvering speed is the greatest safe speed for abrupt maneuvers or for very rough air. Upon encountering severe gusts, the pilot should reduce air speed to maneuvering speed in order to lessen the strain upon the aircraft structure. For airplanes in which the maneuvering speed is not specified, it can be safely computed as 70 percent greater than normal stalling speed (stalling speed multiplied by 1.7).

Flap Speed

If airplanes are equipped with flaps, a maximum speed for use of

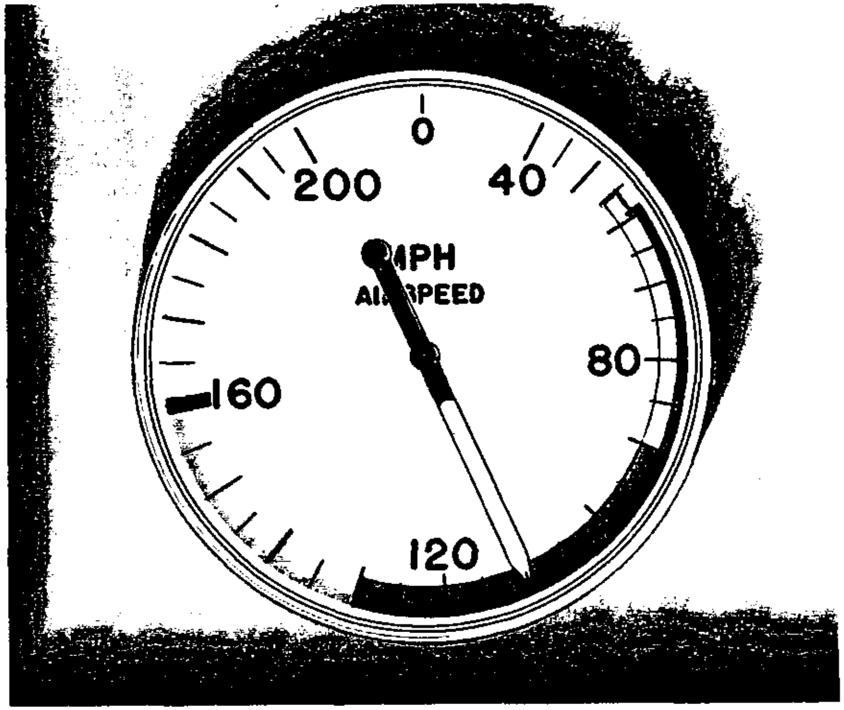


Figure 14. Colored bands on air-speed indicators enable pilots to determine the range of operating speeds at a glance. Red indicates the never-exceed speed; yellow, the cautionary range; green, the normal operating range; and white, the flap operating range.

flaps is specified in the operating limitations. If flaps are used at higher speed than specified, they will be subjected to severe strain which may result in structural failure.

When flaps are extended for landing they should not ordinarily be retracted until the airplane is in contact with the ground. If an approach for landing is missed, flap-setting should not be changed until power has been applied and the airplane has regained normal climbing speed.

When flaps are used on take-off, they should not be retracted until the airplane has cleared obstructions and gained adequate speed. Retracting flaps while in slow flight may cause a sudden drop of 50 feet or more and may even produce a stall.

Markings on Air-Speed Indicator

As a reminder to the pilot, the air-speed indicator is marked to show speed limitations at a glance.[1] Never-exceed speed is designated by a red radial line. A cautionary range between never-exceed speed and maximum normal operating speed is shown by a yellow arc. The range from normal operating speed to normal stalling speed is shown by a green arc. If the airplane is equipped with flaps, the flap operating range is shown by a white arc. (See figure 14.)

The loading of an airplane has a vital effect upon its performance. Weight and balance limitations are specifically set forth in the operating limitations in the airplane. The maximum number of passengers, maximum quantity of fuel, and weight of baggage are specified not so much because a greater load may cause structural failure in flight, but because flight characteristics with an abnormal load undergo a radical and unpredictable change. The take-off run would be excessive, rate-of-climb much slower, landing speed faster, stalling speed higher, and all operating limits drastically reduced.

In many airplanes the pilot may have his choice of different sets of values. He may wish to utilize all the seating capacity and carry less fuel and baggage; or he may prefer to carry a full fuel supply and fewer passengers. The fact that an airplane is adapted for different uses does not mean that it is capable of carrying maximum loads of passengers, baggage, and fuel *at the same time*.

Even though the total load may be no greater than specified, an incorrect distribution may disturb the balance and make the airplane unsafe. Overloading the baggage compartment, for instance, may not only place an excessive strain on the compartment itself, but may

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[1] All new airplanes approved under regulations effective in 1945 are required to have these markings on the air-speed indicator. Airplanes of older design should also have the air-speed indicators so marked by the owners.

also produce a tail-heavy condition, making the airplane hard to handle in the air and easily susceptible to uncontrollable stalls and spins.

Maintenance

If an airplane is to remain safe for flight, it must be properly maintained. Federal Aviation Regulations require that an aircraft shall not be flown unless within the preceding 12 calendar months it has been given a periodic inspection conducted by an appropriately-rated certificated mechanic who holds an inspection authorization, an FAA-approved repair station rated for the aircraft, or the manufacturer of the airplane. (Airplanes used, for hire, to carry passengers or to instruct students must be given additional inspections.) With proper care, the airplane will normally remain airworthy until the next inspection period.

Any unusual conditions, such as excessive strain incurred in flight, hard landings, or abuse in the hangar, may make additional inspections advisable. Frequent additional inspections give the pilot assurance that his airplane is thoroughly airworthy, and often reduce cost of operation by revealing small indications of malfunctioning which may be remedied cheaply and quickly before developing into serious defects calling for major repairs.

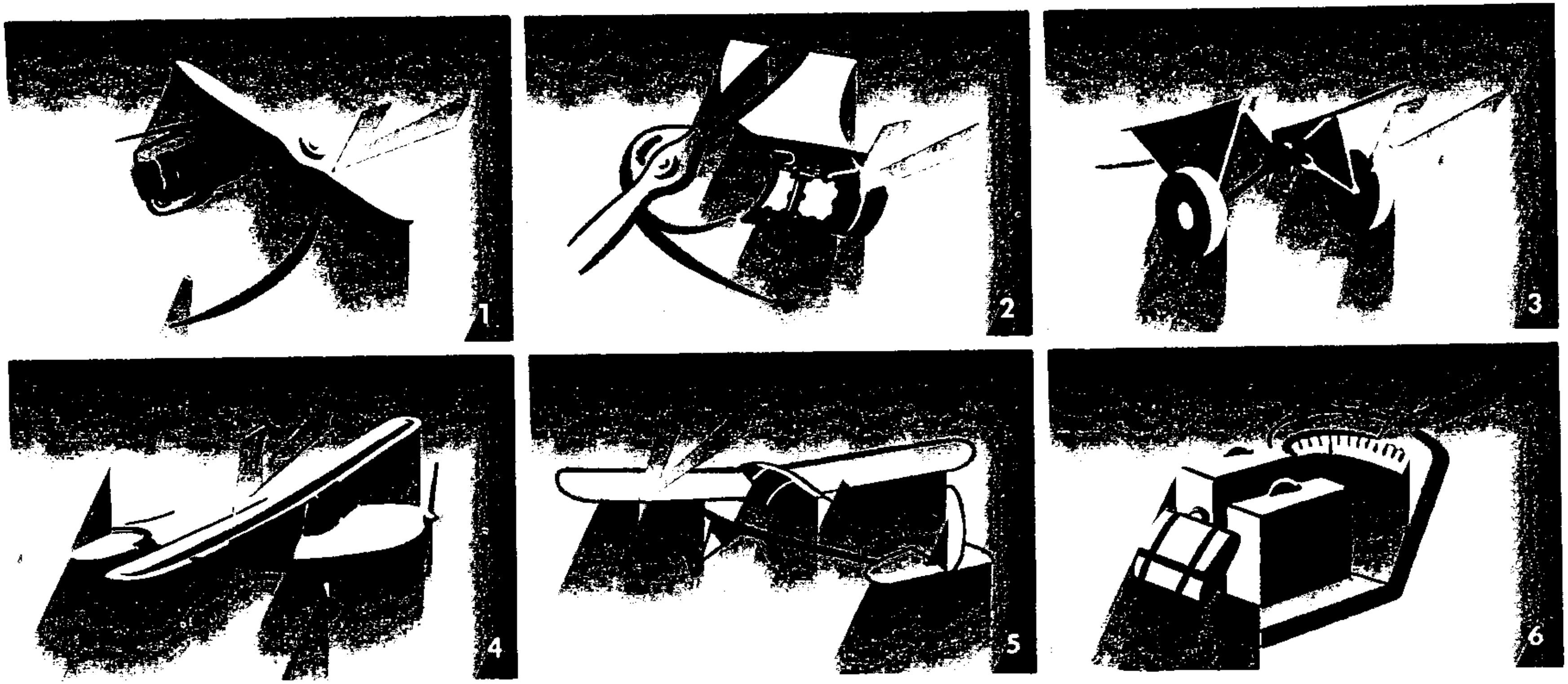


Figure 15. Preflight inspection should include: (1) propeller; (2) engine; (3) landing gear; (4) wings and fuselage; (5) control surfaces and controls; (6) weight of baggage and passengers.

Minor maintenance, such as changing tires, replacing spark plugs, draining the oil, etc., is not classed as repair or alteration and may be performed by the owner.

Preflight Inspection

A careful pilot will always conduct a routine inspection before flight. By always beginning at a certain point and using an orderly procedure, the check can be made systematically and quickly. It should include at least the following items, all of which are not depicted in figure 15.

Cockpit

Battery (or master) and ignition switches should be checked in the OFF position. The landing gear handle (if retractable-gear type) should be checked in the DOWN position.

Powerplant

Propeller.—Check for nicks and cracks, tightness of hub, safetying of nuts.

Engine.—Check for tightness and safetying of all parts (including cowling). Check for security of all fuel lines and oil lines and look for fuel and oil leaks. Check exhaust manifolds for tightness and absence of cracks or holes (a broken exhaust manifold is a fire hazard).

Fuel and Oil.—Check supply visually—do not rely on gauges. Drain a substantial amount of fuel from the fuel strainer (gascolator) and fuel tank drains (to check for contaminated fuel). Check to see that fuel caps (and oil caps) are fastened securely in order to avoid fuel (or oil) syphonage with resulting fire hazard and possible fuel (or oil) starvation. Be sure that fuel (and oil) vents are open and properly aligned to insure proper pressure in the fuel (or oil) tanks, so that proper fuel (and oil) flow will be maintained.

Landing Gear

Check tires for cuts, cracks, and proper inflation. Check struts for proper inflation and fittings for safetying and evidence of cracks, bends, or wear. Lubrication should be adequate but not excessive. Check brake assemblies and look for possible hydraulic leaks.

Wing, Fuselage, and Tail Surfaces

Check covering for holes or wrinkles (wrinkles may indicate internal damage). Check control cables for tension. Check fittings and cables for wear and safetying. Check ailerons, rudder, and elevator for tightness and freedom of movement. Check to see that all surfaces are free from mud, snow, ice, and frost.

Pitot-Static System.—Check to see that the static vents are open and that the Pitot tube is unobstructed. Obstructions will result in unreliable readings on the airspeed indicator (and other Pitot-static instruments).

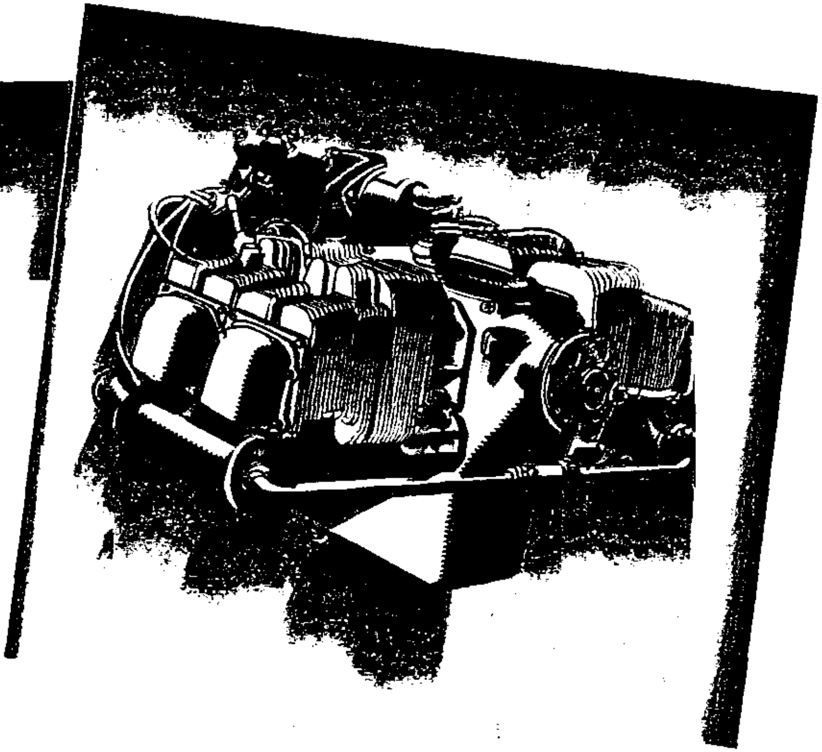
Controls

Check controls for proper movement. Set stabilizer or elevator trim tab for takeoff position.

Check the loading to be sure it does not exceed limitations as given in the FAA-approved Airplane Flight Manual. Be sure that the maximum weight allowance in the baggage compartment is NOT exceeded. This may produce a tail-heavy airplane that has very undesirable flight characteristics and is dangerous.

Note: The Airplane Flight Manual should be checked for further items of importance to be considered during the preflight inspection.

Airplane Engines



The knowledge of a few general principles of engine operation will help you to obtain dependable and efficient service and to avoid engine failure. In this short chapter it is impractical to discuss in detail the various types of engines, and the finer points of operation which you, as a pilot, will learn only through experience. You probably will have access to the manufacturer's instruction manual, you will be familiar with the operating limitations for the airplane, and you will have the benefit of specific advice given by your flight instructor.[1]

How an Engine Operates

Most airplane engines operate upon the same principle as automobile engines. As shown in Figure 16, the mechanism consists of a cylinder, a piston, connecting rod, and a crankshaft. One end of the connecting rod is attached to the piston, and the other end is attached to a crankshaft in order to convert the straight-line motion of the piston to a rotary motion which turns the propeller. At the closed end of the cylinder are two spark plugs (only one shown in Figure 16) to ignite the fuel, and two openings, controlled by valves—one to admit the mixture of fuel and air, the other to permit the burned gases to escape. The operation of the engine requires four strokes of the piston:

Diagram A of Figure 16, shows the piston moving away from the cylinder head. The intake valve is opened and the fuel mixture is sucked into the cylinder.

Diagram B shows the piston returning to the top of the cylinder. Both valves are closed, and the fuel mixture is being compressed.

When the piston is approximately at the top, a spark from the spark plug ignites the mixture which burns very rapidly. The expansion of the gas in burning exerts pressure on the piston, forcing it downward in the power stroke, shown in diagram C.

Just before the piston completes the power stroke, the exhaust valve opens, and the burned gases are forced out as the piston returns to the top of the cylinder, where it is ready to begin the cycle again (diagram D).

From this description it can be seen that a 1-cylinder engine delivers

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[1] Many of the comments in this discussion of engines and recommended flight speeds do not apply to engines equipped with superchargers or with variable-pitch propellers (multiposition or constant speed). Proper methods to obtain best performance with such engines vary with each installation, and the only sources of accurate information are operating limitations or the airplane flight manual.

power only once in every 4 strokes of the piston. The momentum of the crankshaft carries the piston through the other 3 strokes. To increase power and gain smoothness of operation, other cylinders are added and the power strokes are timed to occur at successive intervals during the revolution of the crankshaft. Engines used in light airplanes usually have 4 cylinders; those on heavier airplanes may have as many as 28 cylinders.

Cooling of the Engine

The burning of fuel within the cylinders produces intense heat, most of which is expelled through the exhaust. Much of the remaining heat, however, must be removed to prevent the engine from overheating. In practically all automobile engines excess heat is carried away by water circulating around the cylinder walls. Most airplane engines are built with fins projecting from the cylinder walls so that heat will be carried away by air flowing past the fins.

When an engine is operating on the ground, very little air flows past the cylinders (particularly if the engine is closely cowled) and overheating is likely to occur. Overheating may also occur during a prolonged climb, because the engine is usually developing high power at relatively slow air speed, and the airflow may be insufficient to provide adequate cooling.

Operation of the engine at a temperature in excess of that for which it was designed will cause loss of power, excessive oil consumption, and knocking. It will also lead to serious permanent injury, scoring the cylinder walls, damaging the pistons and rings, burning and warping the valves.

For engines equipped with a cylinder-head temperature gage, the proper operating temperature can readily be determined. Many light engines, however, do not have such a gage, and the pilot must rely on the oil-temperature gage to indicate engine temperature.

Oil is used primarily to lubricate the moving parts of the engine. It also serves, however, to help reduce engine temperature by removing some of the heat from the cylinders. The pilot should keep a constant check on oil gages because a variation beyond normal limits indicates engine trouble which calls for an immediate adjustment or landing to prevent serious damage. Use of the kind of oil specified by the engine manufacturer will prevent expensive repairs which inevitably result from improper lubrication. Different brands of oil should not be mixed. Such mixture may produce gum and sludge which will cause sticking valves and piston rings.

Proper Fuel Essential

The engine requires the proper fuel if it is to operate satisfactorily. Automobile gasoline should not be used because it is likely to contain gums and harmful substances which make it unfit for airplane engines. Furthermore, automobile gasoline has a much higher vapor pressure than aviation gasoline, which may produce "vapor-lock," the vaporization of gasoline in the fuel lines preventing the flow of fuel to the carburetor.

Aviation gasolines are classified by "octane ratings" and "performance number" power ratings. The proper fuel rating for the engine (specified by the manufacturer) is always found in the operating limitations and usually is placarded at the fuel filler opening. The use of aviation gasoline with a rating higher than specified does not improve the engine operation, and it may, in some cases, prove harmful. Aviation gasoline with a lower rating is definitely harmful and should not be used under any circumstances, because it causes loss of power, excessive heat, burnt spark plugs, burnt and stuck valves, high oil consumption, and detonation.

The fuel mixture in most engines can be changed from "rich" to "lean" by an adjustment in the cockpit. Inexperienced pilots need a word of warning about the use of this control. At high altitudes, where the air is less dense, the mixture may be "leaned out" somewhat to reduce fuel consumption and obtain smoother engine operation. At altitudes of less than 5,000 feet, a lean mixture may cause serious overheating and loss of power. The fuel mixture should never be "leaned out" unless the leaning produces an increase in r.p.m. at the same throttle setting (on airplanes equipped with fixed-pitch propellers).

Detonation, which is easily detected in an automobile engine by a "pinging" sound, may not be heard in an airplane engine because of other noises. When the engine is operating normally, the spark plugs ignite the fuel at the proper instant, and the fuel burns and expands rapidly, exerting an even pressure on the piston. Detonation occurs when the

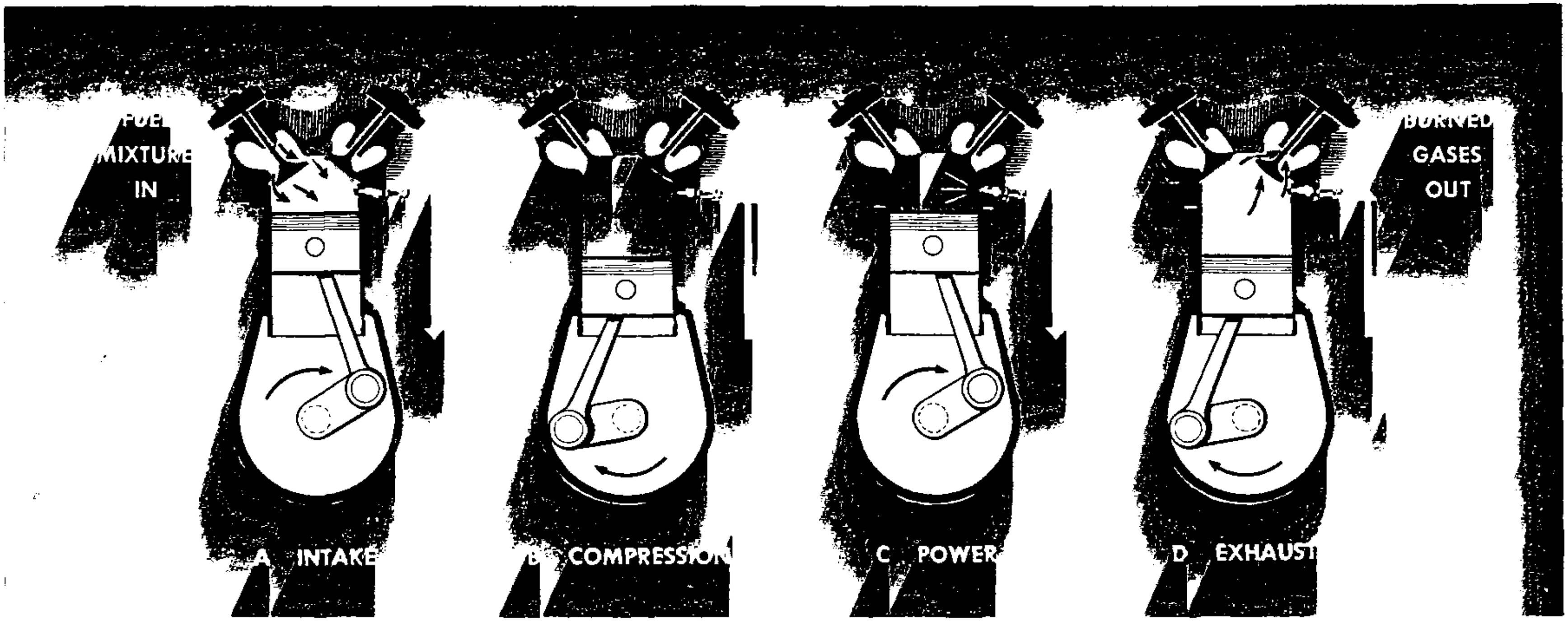

Figure 16. These diagrams of an engine cylinder show how four strokes of the piston produce power. (A) The fuel mixture (light blue) is drawn into the cylinder by a downward stroke. (B) Upward stroke compresses the mixture (darker blue). (C) The spark ignites the mixture (red), forcing the piston downward and producing power which turns the propeller. (D) Upward stroke pushes burned gases (light red) out of cylinder.

fuel explodes instead of burning evenly. The resulting shock causes loss of power and frequently leads to serious trouble. As already stated, detonation may be produced by overheating, low grade fuel, or too lean a mixture. It may also be caused by opening the throttle abruptly when the engine is running at slow speed. To prevent detonation, therefore, the pilot should use the correct grade of fuel, maintain a sufficiently rich mixture, open the throttle smoothly, and keep the temperature of the engine within recommended operating limits.

Carburetor Icing

Carburetor icing is a frequent cause of engine failure. The vaporization of fuel, combined with the expansion of air as it passes through the carburetor, causes a sudden cooling of the mixture. The temperature of air passing through the carburetor may drop as much as 60° F. within a fraction of a second. Water vapor in the air is "squeezed out" by this cooling and, if the temperature in the carburetor reaches 32° F. or below, the moisture will be deposited as frost or ice inside the carburetor passages. Even a slight accumulation of this deposit will reduce power and may lead to complete engine failure, particularly when the throttle is partly or fully closed. (See fig. 17.)

The carburetor heater is an anti-icing device which preheats the air before it reaches the carburetor, thus melting any ice or snow entering the intake and keeping the fuel mixture above freezing point. On dry days, or when the temperature is well below freezing, the moisture in the air is not sufficient to cause trouble; but if the temperature is between 20° and 70° F., with visible moisture or high humidity, the carburetor heater should be turned on to forestall icing. The heater is adequate to prevent icing, but it will not always clear out ice which already has formed. The first indication of icing usually is a roughness in engine operation, together with a loss of r.p.m. (loss of manifold pressure if a constant-speed propeller). If this occurs, heat should be turned full-on immediately to prevent rapid accumulation.

During prolonged glides with closed throttle the carburetor heater may not provide sufficient heat to prevent icing unless the throttle is opened periodically to keep the engine warm. Preheating of the air tends to reduce the power output of the engine and to increase the operating temperature. Therefore, the carburetor heater should not be used on warm, dry days (when the engine may overheat), nor used on take-off (when full power is required) unless weather conditions are such as to make the use of preheat desirable.

A fuel strainer is incorporated in the fuel line near the carburetor for the purpose of collecting sediment and water which may drain from the fuel tanks. A substantial amount of fuel should be drained from this fuel strainer (and also from each fuel tank sump) prior to each flight to eliminate these impurities. The fuel tanks should be filled at the conclusion of a day's flying, so that the air in the tanks will be eliminated, thus preventing condensation of moisture which would cause an accumulation of water in the fuel.

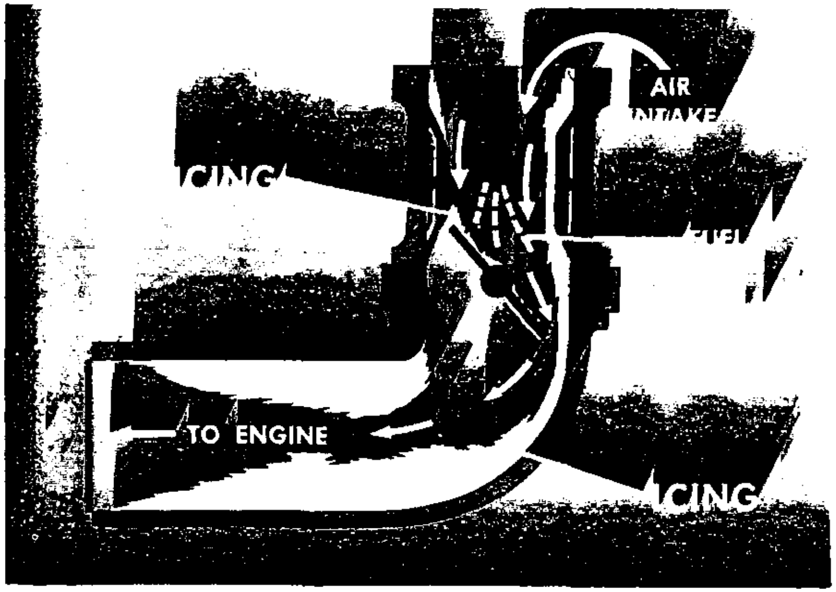

Figure 17. Formation of ice (white) in the fuel-intake system may reduce or block the flow of fuel (red) to the engine.

Static electricity, formed by the friction of air passing over the surfaces of an airplane in flight, creates a fire hazard when refueling. To guard against the possibility of a spark igniting the fuel, a ground wire should be attached to the aircraft before the cap is removed from the tank. The refueling nozzle should be grounded by being kept in contact with the plane's fuel tank. Any fuel which is spilled in filling should be wiped off immediately. Vent holes in the tank caps must be open to permit fuel to flow from the tanks without creating suction which would prevent the flow and cause the engine to stop.

Idling Procedure

Whenever the throttle is closed during flight, the engine cools rapidly and vaporization of the fuel is less complete than if it were warm. Furthermore, the airflow through the carburetor system under such conditions is not sufficiently rapid to assure a uniform mixture of fuel and air. Consequently, the engine may stop because it is receiving too lean a mixture ("starving") or too rich a mixture ("loading up"). An abrupt opening or closing of the throttle may aggravate this condition, and the engine may cough once or twice, sputter, and stop.

Three precautions should be taken to prevent the engine from stopping while idling. First, make sure that the ground-idling speed is properly adjusted (about 550 to 600 r. p. m. minimum for most light engines). Second, do not open or close the throttle abruptly. Third, keep the engine warm during glides by frequently opening the throttle halfway for a few seconds.

Starting the Engine

Before starting the engine, move the airplane to a position clear of other aircraft, where the propeller will not stir up gravel or dust to injure property or cause annoyance. The wheels should be held firm, either by adequate parking brakes or by blocks placed in front of the wheels.

With the switch in "off" position, rotate the propeller through two complete revolutions of the crankshaft to detect any oil that may have accumulated in the cylinders and to "prime" the engine by drawing a charge of fuel into the cylinders. The exact procedure for starting differs with various engines, and the pilot should be familiar with the operating manual for his particular engine.

If the engine has a starting device, the pilot should make sure that no one is in front of the propeller. He should always call "all clear," wait for a response, and then call "contact" before engaging the starter.

Swinging the Prop

If the airplane has no starting device, the person who is going to turn the propeller will call "gas on, switch off, throttle closed, brakes on," which the pilot will check and repeat. The switch and throttle must not be touched again until the person swinging the prop calls, "contact." The pilot will repeat "contact" and *then* turn on the switch—never turn on the switch and then call "contact."

If you are swinging the prop yourself, a few simple precautions will help you avoid accidents.

When touching a propeller, always assume that the switch is on, even though the pilot may confirm your statement "switch off." The switches on many engine installations operate on the principle of short-circuiting the current. If the switch is faulty, as sometimes happens, it can be in "off" position and still permit the current to flow to the spark plugs just as if it were "on."

Be sure the ground is firm. Slippery grass, mud, grease, or loose gravel might cause you to slip and fall into or under the propeller.

Never allow any portion of your body to get in the way of the propeller. This applies even though the engine is not being cranked; occasionally, an engine which is warm will backfire after it has been stopped for a minute or two.

Stand close—but not too close—to the propeller and step away as it is pulled down. If you stand too far away from the propeller, you must lean forward to reach it. This throws you off balance and you may fall into the blades as the engine starts. Stepping away after cranking provides a safeguard in case the brakes give way.

Figure 18. "Swinging the prop" is a safe operation if a few simple precautions are observed.

In swinging the prop, always move the blade downward by pushing with the palms of the hands. If you push the blade upward, or grip it tightly with your fingers, backfiring may break your fingers or draw your body into the path of the blades. (See fig. 18.)

If you are to remove blocks from in front of the wheels, remember that the propeller when revolving is almost invisible. Cases are on record where a person intending to remove the blocks attempted to walk directly through the propeller.

Starting in Emergencies

If no competent person is available to start the engine or to handle the controls while it is being started, you may be required to start the engine without assistance. Make sure under those circumstances that the wheels are chocked with blocks large enough to prevent the plane from moving forward, and that the control stick (front seat only) or wheel is held fully back (in tail-wheel type) by tying it with the safety belt.

In airplanes of low horsepower, the propeller may be swung with one hand while standing behind it and holding onto a strut with the other hand to keep the body from being overbalanced. This is the usual method of starting low-powered seaplanes.

As soon as the engine starts, the throttle should be advanced to obtain the recommended warm-up r. p. m. (usually 700 to 1,000) and the oil-pressure gage checked immediately. Unless the gage indicates oil pressure within a few seconds, the engine should be stopped, and the cause discovered. If the oil is not circulating properly, the engine can be seriously damaged within 2 or 3 minutes.

The engine must reach normal operating temperature before it will run smoothly and dependably. Many accidents are attributable to attempts to take off with a cold engine. The correct temperature will be indicated, of course, by the cylinder-head temperature gage. However, if the engine is not equipped with such a gage, the pilot is dependent upon the oil-temperature gage. He will find that the oil warms very slowly in cold weather, and the engine will be ready for take-off before the oil-temperature gage indicates normal operating temperature. Under these conditions he may assume that his engine is sufficiently warm when (1) the oil-pressure gage has moved close to a proper reading and (2) the throttle can be advanced to full power and back without causing missing or backfiring.

Just before take-off, the engine operation should be thoroughly checked, including full-power output, operation on each magneto separately (the drop in r. p. m. should not be more than 100 when switching from two magnetos to one magneto). Idling speed should not be less than 550 to 600. The exhaust smoke should be light gray, or colorless. If blue, it indicates that too much oil is being burned; if black, the mixture is too rich.

To enable the pilot to check operation quickly and easily, engine instruments are marked in much the same way as the air speed indicator. A red line indicates maximum or minimum limits, and a green arc indicates normal operating range. (See fig. 19.)

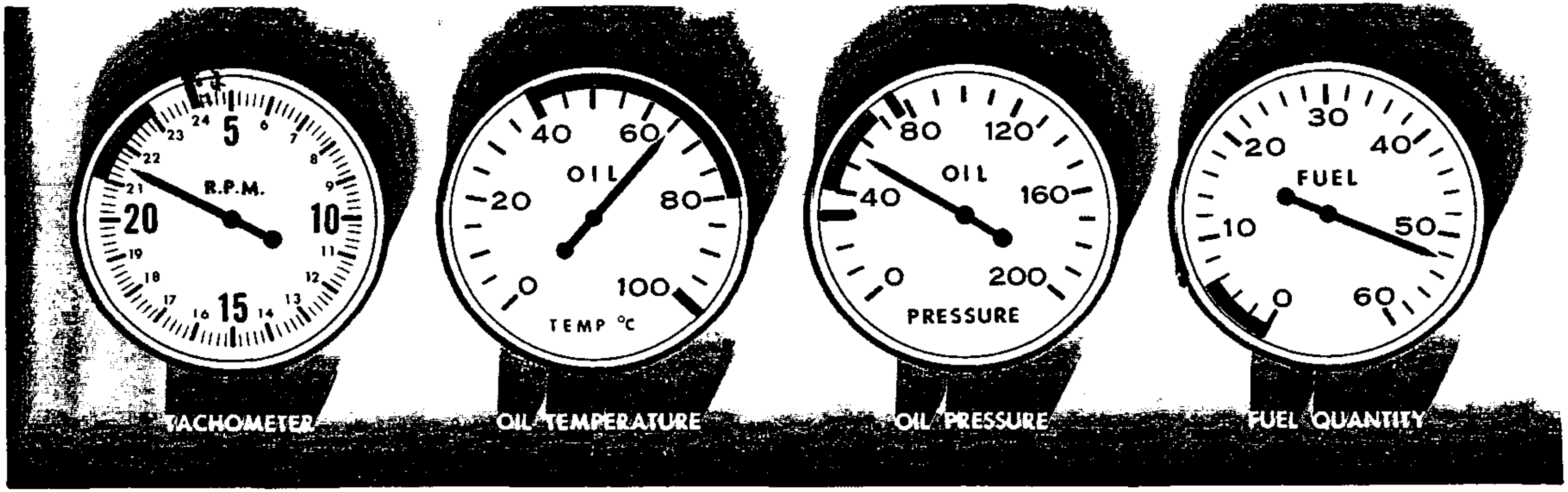

Figure 19. Dials of engine instruments are marked in colors to help the pilot make quick and easy checks of engine performance. The markings indicate normal operating ranges and also minimum and maximum limits.

Flying the Plane

A pilot familiar with the basic laws of flight, the characteristics of stalls and spins, the limitations of his airplane, and the proper operation of his engine can fly with confidence, developing skill through training and practice. This chapter is intended to supplement the teaching of your flight instructor by emphasizing proper techniques in normal flight: take-off, cruising, and landing.

Just prior to take-off, you should check at least the following items:

1. Altimeter setting.
2. Freedom and correct movement of all flight controls.
3. Trim tab setting for take-off position.
4. Flaps (if any) for take-off position.
5. Fuel quantity, and valve in "ON" position.
6. Fuel mixture—RICH (if below 5,000 feet).
7. Propeller (if constant-speed type)—high r.p.m.
8. Carburetor heat—cold.
9. Oil pressure and temperature, and fuel pressure.
10. Engine r.p.m. on each magneto separately.
11. Engine r.p.m. at full throttle.

Take-Off Procedure

The take-off should always be started at the extreme end of the runway. This will give you advantage of the entire length available, and will enable you to discontinue the take-off should you sense anything wrong in the early stages.

After receiving take-off clearance (or rechecking the traffic if there is no control tower) you should head the airplane down the runway and smoothly open the throttle. When the controls become effective, place the airplane in an attitude corresponding to a shallow climb. The airplane will then leave the ground when it has acquired sufficient speed.

In a crosswind take-off the airplane should attain greater speed before leaving the ground. The excess speed will prevent it from settling back on the ground with possible damage to the landing gear due to drifting motion. For crosswind take-offs you should place the airplane in level flight attitude, wait until it has attained the speed used for normal climb, and then "lift it off" by a slight backward pressure on the stick. To prevent drift after take-off, the windward wing should be lowered slightly.

Take-off performance—that is, the length of ground-run required and the rate-of-climb—is affected by several factors.

One of these factors is the design of the airplane, involving the "power-loading" (the ratio of gross weight to horsepower) and the "wing-loading" (the ratio of gross weight to wing area). A very little difference in weight makes a considerable difference in ability to take off quickly, and therefore is particularly significant when flying from short fields or at high altitudes. If there is any question as to the ability of the airplane to make a safe take-off and climb, the weight should be reduced to a minimum by limiting the amount of baggage, the number of passengers, and the quantity of fuel.

The condition of the runway surface also affects take-off. Long grass, soft ground, mud, snow, or water will set up resistance. That necessitates a greater length of runway for the airplane to gain flying speed.

A take-off under no-wind conditions, or into a very light wind, will require a longer runway than a take-off into a moderate or strong wind.

Another factor, sometimes overlooked by pilots, is the effect of atmospheric conditions—temperature, humidity, pressure, and altitude.

On a very cold day an airplane may take off after a run of 800 feet and climb at the rate of 600 feet a minute, clearing obstructions close to the boundary without the slightest difficulty. The same airplane, flying from the same field on a very hot day may require 1,300 feet for take-off (an increase in distance ranging from 50 percent to 75 percent) and may climb at only 450 feet a minute.

Higher altitudes or lower atmospheric pressures also increase the take-off distance and reduce the rate-of-climb. An airplane which requires 800 feet for take-off from a field at sea level may require more than 1,600 feet to take-off from a field at 5,000 feet elevation. The maximum rate of climb might be reduced from 600 feet per minute at sea level to 250 feet per minute at 5,000 feet altitude.[1]

Engine Failure on Take-Off

If engine failure should occur at low altitude, you should immediately drop the nose to prevent a stall. While you are establishing a normal glide you have a few seconds in which to decide on the next move. Unless you are *positive* that you have sufficient altitude for a 180° turn and downwind landing, your best procedure is to continue straight ahead, landing into the wind or slightly crosswind. Even though the terrain may be entirely unsuited for landing, there is less probability of serious injury if you reach the ground in normal landing attitude than if you stall or spin into the ground while attempting to return to the field.

Angle of Climb

Upon leaving the ground, hold the plane level to gain additional speed before entering the climb. Sometimes a pilot will take off at minimum flying speed and immediately point the nose of his airplane upward at a steep angle, under the delusion that he is obtaining

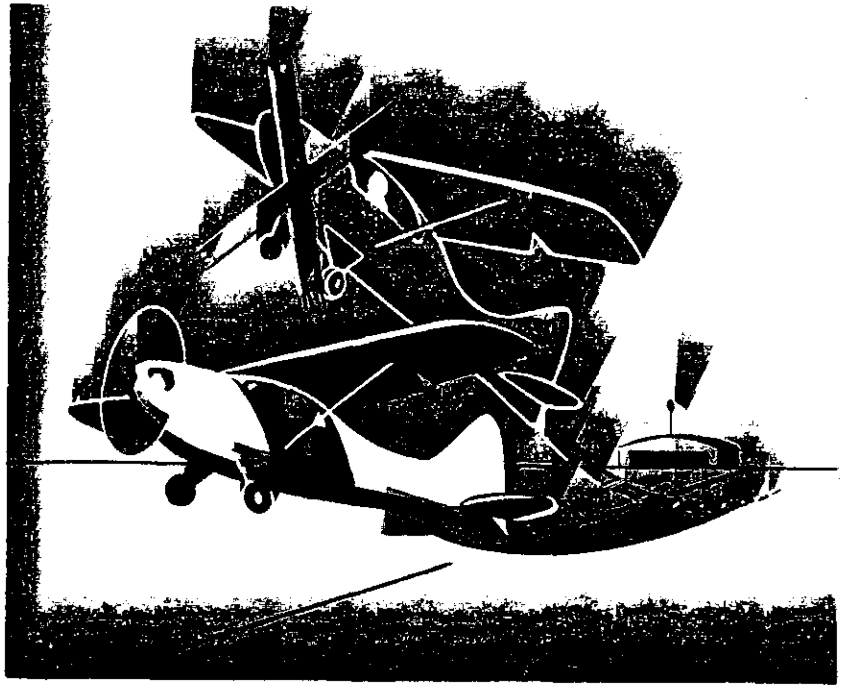

Figure 20. Climbing at a steep angle during a take-off is not only inefficient but also dangerous.

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[1] Variation in take-off and climb due to atmospheric conditions is presented in tabular form in the Appendix.

maximum climb. Actually, such a procedure is dangerous because it places the airplane in a critical stalling attitude in case of engine failure or a sudden gust. (See fig. 20.)

Climbing steeply at slow speed is an inefficient way to gain altitude. The best rate of climb for airplanes with fixed-pitch propellers is attained when air speed is about 50 percent greater than normal stalling speed. An efficient take-off method for an airplane with normal stalling speed of 40 m. p. h. is to leave the ground at 50 m. p. h., level off until speed reaches 60 m. p. h., and then enter the climb, maintaining a speed of 60 m. p. h. If you reduce power during the climb, you should lower the nose sufficiently to maintain 60 m. p. h. air speed; if you increase power, raise the nose accordingly. The type of climb just discussed, known as the "best rate of climb," will enable you to reach the greatest altitude in the *least time* at a given power setting.

Clearing an Obstruction

Another type of climb, called the "steepest climb" or "best angle of climb," is sometimes helpful in clearing an obstruction close to the field because it enables you to gain the greatest altitude in the *least horizontal distance*. It is made at an air speed about 25 percent above stalling. If prolonged, however, the "steepest climb" is likely to cause overheating of the engine.

A type of climb called "zooming" should perhaps be discussed briefly. It is executed by attaining considerable air speed, either in level flight or dive, and then pulling the nose up sharply into an excessive angle of climb, holding the airplane in this attitude until it has lost its upward momentum and is about to stall. The zoom merely translates air speed into altitude, and it leaves the plane at a critical angle of attack with insufficient flying speed. Recovery is made by nosing the plane down, thereby losing most of the altitude just gained. A common misconception among pilots is that a zoom is an effective method for gaining altitude to clear obstructions on take-off. Actually, the zoom will not attain as much altitude in a given distance as a steady climb at the best angle of climb. Moreover, it is an exceedingly dangerous maneuver because the slightest misjudgment may lead to disaster. The zoom entered from a dive is a show-off maneuver frequently attempted by irresponsible pilots to amaze their friends. Many of these attempts end in fatalities because the pilot miscalculates the loss of altitude necessary in changing the flight path from a downward to an upward direction, or because he stalls at the end of the zoom—with too little altitude for recovery—and consequently falls or spins to the ground nose-first.

The cruising speed (normal operating speed) is usually established by using sufficient power to provide relatively fast flight without undue wear on the engine or excessive fuel consumption. Most light airplanes with fixed-pitch propellers are operated at about 70 to 75 percent of the maximum horsepower. A simple way to determine this horsepower is to deduct 10 percent from the maximum cruising r. p. m. specified in the Operation Record.[1]

Thus an engine with maximum r. p. m. of 2,000 would be operated at 2,000 minus 200, or 1,800 r. p. m. The advantages in using reduced power far outweigh the benefits of increased speed. For example: in a typical airplane with a 145-horsepower engine, the air speed when operating at 73 percent available horsepower is 110 m. p. h. At full throttle it is 121 m. p. h.—a gain of only 11 m. p. h. But at full throttle the engine consumes 50 percent more fuel than at 73 percent power, and its range is reduced from 4 hours to 2 hours and 40 minutes. Under no-wind conditions, its range in distance is reduced from 440 to 320 miles.

Landing Technique

In an approach for landing it is advisable to use a speed which gives a relatively slow rate of descent (a long glide) and at the same time provides a sufficient safety margin above stalling. The speed recommended for approach is the same as for best climb—50 percent above stalling. Under gusty conditions a slightly higher speed is desirable.

A competent pilot should be able to make three types of landings and to select the type most suitable for the conditions of wind and terrain.

Accuracy Landing

The power-off full-stall landing is commonly used for light airplanes with tail wheels. FAA flight tests require proficiency in "accuracy

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[1] If the airplane is equipped with high-pitch propeller which does not allow the engine to develop the maximum specified r. p. m., the 10 percent should be deducted from the r. p. m. produced in level flight at full throttle.

landings." In making such a landing, the pilot must close the throttle on the downwind leg, turn onto base leg and make final approach without power, touching the ground at a predetermined "spot."

This type of approach and landing is an excellent maneuver for testing skill and judgment; it may also be of some value as preparation for forced landings. In some ways, however, it is the most difficult type to execute properly. Its success depends upon accurate calculation of wind effect, maintenance of a steady air speed and rate of descent, and careful manipulation of the controls while the airplane is flying slowly, near the ground, at a critical angle of attack. Down-currents may cause the airplane to descend too rapidly and fall short of the field; up-currents may carry the airplane beyond the intended landing spot; a gust may produce an unintentional stall; "dropping in" imposes a severe strain on the landing gear; bouncing or "ballooning" may cause loss of control and subsequent damage.

Power-Off Full-Stall

When executing this type of landing, a pilot should not try to touch at the end of the runway, but should select a spot a few hundred feet from the boundary. He thus provides a margin of safety in the event of unexpected down-currents which frequently are encountered at the edge of the landing field. He should keep one hand on the throttle, and never hesitate to use power to correct for errors or to go around the field again for another approach.

As a general practice most pilots employ a modification of the "accuracy landing," making the approach under reduced power, and closing the throttle for a full stall landing only after it becomes evident that the airplane will touch the runway at the desired spot.

Power-On Full-Stall

The power-on full-stall landing is executed by using partial power during the descent, putting the plane into stalling attitude just before it touches the ground, and reducing power still further or cutting it entirely after contact is made with the ground.

This landing is useful for soft terrain—snow, sand, or mud because the nose is slightly higher at the moment of contact and the forward speed is slightly less than in a power-off full-stall landing. If the plane shows any tendency to nose over, the throttle can be opened and the propeller blast on the tail will help to keep the plane in the three-point position (for tail-wheel type airplanes).

Wheel Landing

The wheel landing is executed by using partial power during the descent, leveling off just before touching the ground, and making contact with the landing wheels while the tail is only slightly lower than in level-flight position. The throttle need not be fully closed until the plane has settled on the wheels in complete contact with the runway. The control wheel or stick should be moved forward slightly as the wheels touch the runway, in order to prevent the plane from bouncing and also to keep it firmly on the ground if the air is gusty during the landing roll. This landing is generally used for airplanes with tricycle landing gear (nose wheel), and for heavy aircraft. The level attitude of the airplane upon landing gives the pilot better vision over the nose than is possible with a full-stall landing.

The wheel landing is particularly useful for light planes whenever the wind is strong or gusty. The airplane makes ground contact while it is still maintaining flying speed, and thus passes from positive air control to positive ground control without the intermediate critical period characteristic of the full-stall power-off landing. There is no danger of an unintentional stall in this landing. If the tail is held high until all flying speed is lost, there is no tendency for a gust to lift the plane back into the air once it has touched the ground.

Obviously, the speed at the moment of contact is much greater in the wheel landing than in the other two landings just discussed. If the plane is of the nose-wheel type, brakes can be applied almost immediately after contact with the ground (once the nose wheel is on the ground). For the tail-wheel type, the distance required to bring the airplane to a stop is greater. Therefore, the wheel landing is impractical for very short runways, or even runways of moderate length, unless the landing is made at the near end of the runway, and the wind is sufficiently strong to prevent a possibility of running into the field boundary.

For take-off, climb, cruising, and landing, two flight instruments constantly used are the air-speed indicator and the altimeter. Because both of these instruments are affected by changes in atmospheric pressure, the pilot needs to know the corrections and adjustments necessary to obtain correct readings.

The Air-Speed Indicator

The air-speed indicator registers the impact of air upon the airplane, and translates this pressure into air-speed readings of knots or miles per hour.

Air-speed indicators are calibrated for density of the air at standard sea-level pressure of 29.92 inches of mercury and a temperature of 59° Fahrenheit. Under any other conditions, a correction must be applied to the air-speed reading to obtain the true air speed. A general rule for making the correction is to add 2 percent of the indicated air speed for each 1,000 feet of altitude. Thus, for an indicated air speed of 120 m.p.h. at 5,000 feet, the correction would be 2×5, or 10 percent of 120 which is 12. Adding 12 to 120 gives 132 m.p.h., the true air speed.[2] For accurate computation of time, ground speed, and distance, indicated air speed should be converted to true air speed.

An important point for pilots to understand is that although a correction is usually necessary to obtain true air speed, the air-speed indicator, without correction (indicated air speed) is a reliable guide to show stalling speed and other air speeds associated with flight maneuvers. The changes in atmospheric pressure which affect flight characteristics of airplanes affect the air-speed indicator in much the same way. For example, an airplane which stalls at a true air speed of 50 m. p. h. at sea level where the air is dense will probably stall at a true air speed of 60 m. p. h. at 10,000 feet altitude where air is thinner. However, the indicated air speed in both instances would be 50 m. p. h. because the impact of the heavier air at a speed of 50 m. p. h. would be equivalent to the impact of the lighter air at a speed of 60 m. p. h. Thus, a pilot who is familiar with the proper air speeds for take-off, climb, glide, cruising, landing, etc., need not convert indicated air speed to true so far as maneuvers are concerned, but may take his readings directly from the air-speed indicator.

The air-speed indicator should be checked occasionally to make sure it is working properly. Leaks may develop in the tubing, or moisture may collect. Vibration may destroy the sensitiveness of the diaphragm, or the instrument may be ruined by thoughtless people who sometimes blow or suck on the tubes. Any dirt or dust, or in the

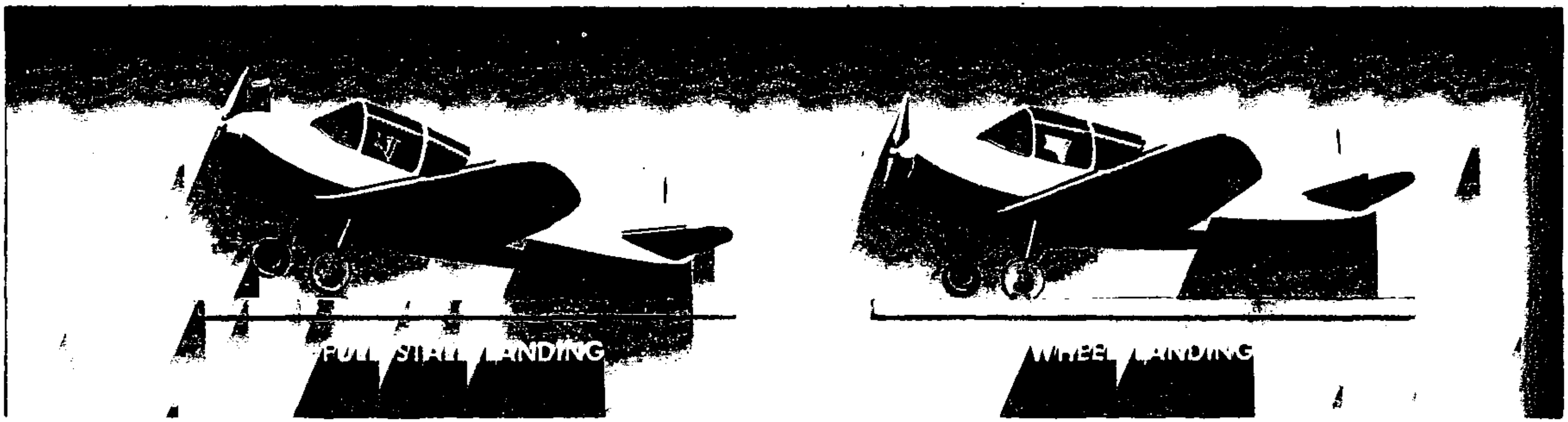

Figure 21. In a "full-stall landing," with power either on or off, the tailwheel and front wheels touch the ground at the same time. In a "wheel landing," front wheels make first contact with the ground and tail wheel is kept off the ground while plane loses forward speed.

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[2] For absolutely accurate correction the temperature and pressure altitude must be considered, but this is not necessary when flying by Visual Flight Rules (VFR).

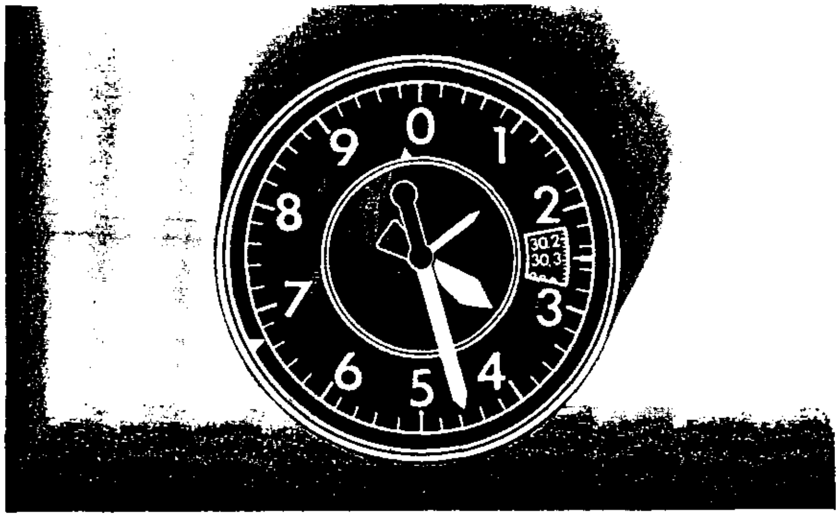

Figure 22. The altimeter is set, by means of the knob, so that the prevailing barometric pressure appears in the "altimeter setting" window at the right. The small hand is the 10,000-foot hand; the medium hand is the 1,000-foot hand; and the large hand is the 100-foot hand. The altimeter registers 13,455 feet.

wintertime ice and snow collecting at the mouth of the tube, will obstruct the passage of air and prevent the instrument from giving correct indications.

The Altimeter

The altimeter is a form of barometer which measures atmospheric pressure, and registers this pressure in terms of altitude.

For correct reading, the instrument must be set to correspond with the actual barometric pressure at the time and place of flight corrected to sea level. This is referred to as the "altimeter setting." When the airplane is on the ground, the dial or hand may be rotated (by an adjusting knob provided for this purpose) so that the pointer indicates the actual field elevation as shown on the aeronautical chart. For example, if the field elevation is known to be 750 feet, the altimeter should be set to read 750 feet.

Sensitive altimeters, and standard altimeters with a barometric scale, have a small window (altimeter-setting window) in the face of the dial indicating the barometric pressure at the field (corrected to sea level) as a check on the accuracy of the instrument. When in flight, the current altimeter setting may be obtained by radio, and the instrument can be set with the proper reading in the altimeter setting window. Upon landing, the altimeter, if correctly calibrated, will then read the exact elevation of the field.

The altimeter, when properly set, will indicate the approximate height of the airplane above sea level. The height above an airport or the terrain immediately below can easily be ascertained. It is the difference between the altimeter reading and the known elevation of the airport or terrain as shown on the chart.[3]

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[3] For absolute accuracy of altimeter reading, a correction must be applied for variation in temperature; but this refinement is not necessary for VFR flight.

Airport Traffic

At landing fields not equipped with control towers, the entire responsibility for avoiding accidents rests upon you—the pilot.

When taxiing go slow and, unless your visibility is unrestricted, use a zig-zag pattern to see that your path is clear at all times. Before crossing any runway, make sure that no planes are approaching on take-off or landing. Immediately before take-off make sure that the runway is clear, and check incoming traffic. Aircraft approaching for a landing have right-of-way. A plane on the ground should face incoming traffic and delay take-off until there is absolutely no danger of collision.

After take-off, continue straight flight until you have reached the airport boundary and have gained at least 500 feet of altitude. After checking for other aircraft, you may then make a turn 90° to the left (at airports using left-hand traffic), followed by a turn of 45° to the right to leave the traffic pattern. All turns in the vicinity of an airport must be to the left unless otherwise specified.

Before landing you should circle the field sufficiently to observe traffic, to determine wind direction and velocity, and to note which runway is being currently used. The wind direction is indicated by a wind sock, a wind tee, or tetrahedron. Sometimes, even after a very short flight, you may return to the field and find that the wind has shifted. That means, of course, that you may have to use a different runway from that which you used for take-off.

Special care is necessary on the final approach to see that the runway is clear and that no other plane is approaching from a slightly different angle or at a different altitude. Do not insist on your "right-of-way." The pilot in the other plane may not see you in time to avoid an accident; his visibility may be restricted or his attention may be diverted.

At airports which have control towers, the operator is able to assist pilots in avoiding collisions both on the ground and in the air. All pilots are required to observe and follow directions issued by light signals or radio, but this does not relieve them of the necessity of exercising due care and good judgment in carrying out the instructions.

Light Signals

Light signals from the control tower should be acknowledged by moving ailerons or rudder when on the ground, by rocking the wings when in the air, and by flashing the landing or navigation lights at night. The correct interpretations of signals from an airport traffic control light are given in the following table:

Color and Type of Signal	On the Ground	In Flight
STEADY GREEN	Cleared for take-off	Cleared to land.
FLASHING GREEN	Cleared to taxi	Return for landing (to be followed by steady green at proper time).
STEADY RED	Stop	Give way to other aircraft and continue circling.
FLASHING RED	Taxi clear of landing area (runway) in use.	Airport unsafe—do not land.
FLASHING WHITE	Return to starting point on airport.	
ALTERNATING RED AND GREEN.	General Warning Signal—Exercise Extreme Caution.	

Use of Radio

Radio is the most effective means of traffic control, issuance of instructions by use of lights being very limited. Traffic is almost entirely controlled by radio at most airports where control towers are located; and a majority of light aircraft which fly the airways are equipped with two-way radio. Two-way radio comunication is required of all aircraft taking off or landing at an airport at which an FAA-operated control tower is located unless prior authorization is obtained from the tower.

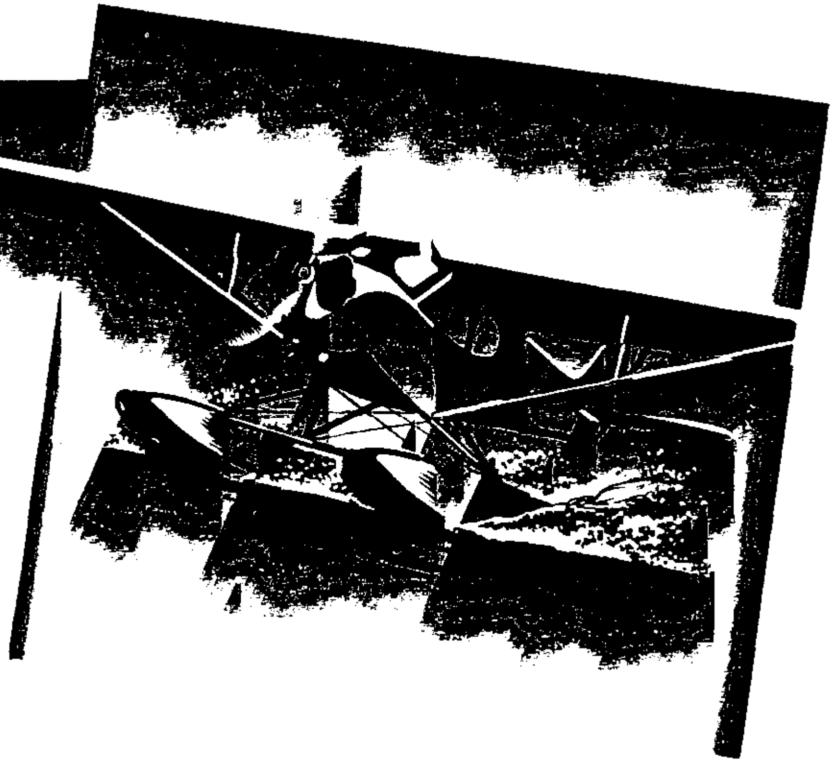
Federal Aviation Regulations require that pilots obey instructions given by either radio or lights from the control tower. When ready to taxi prior to departure, a pilot calls the control tower by radio for taxi and take-off instructions. He follows the tower operator's instructions before and during take-off, continuing to keep his set tuned to the tower frequency until he is out of the control zone.

A pilot approaching an airport under VFR conditions calls the tower when he is several miles from the field. He remains in radio contact with the tower and follows the approach and landing instructions given by the tower operator. Control by the tower continues until the plane has been parked.

In addition to being important in traffic control at airports, radio is a valuable aid in cross-country flying. In order to make flying safer and easier for pilots, the FAA's Federal Airways System also provides communications facilities, electronic aids to navigation and several other services.

Every pilot of light aircraft should familiarize himself with the use of two-way radio and with the convenience and security it affords. Valuable information on this subject will be found in "Pilots' Radio Handbook" and "Flight Information Manual," two of the publications listed on page 41 as suggested references for further study.

Seaplanes



Seaplanes are handled in the air exactly like landplanes. But taxiing, take-offs, and landings are somewhat different. For this reason a landplane pilot should always obtain adequate instruction before attempting to fly a seaplane.

Taxiing on water usually requires more time than taxiing on land. Consequently there is some likelihood of overheating the engine. To avoid this, the seaplane should be taxied very slowly, with minimum power, or rapidly "on the step" with enough forward speed to make air cooling effective. Slow taxiing, or "ploughing," should be done with the control stick held all the way back in order to raise the nose high and prevent spray from striking the propeller. Fast taxiing involves using enough power to lift the plane "on the step." Power may then be reduced, and the floats will skim along the surface in a planing position at a moderate speed.

Turns out of the wind (downwind) sometimes require considerable power to overcome the "weather-cocking" tendency (the tendency of the seaplane to head into the wind just as the arrow of a wind vane points into the wind). Turns into the wind, on the other hand, must be made very slowly to avoid the combined effect of centrifugal force and cross wind, which may lift the inside wing and bury the outside float, with disastrous results. Approaches to docks, floats, and moorings should be made into the wind where practicable so that the wind force will help to reduce forward momentum after the engine has been stopped.

A landplane pilot must learn a different technique for take-off in a seaplane. When throttle is opened at the beginning of the run, the stick must be held all the way back so that the nose of the plane is kept as high as possible. After initial speed is acquired, the back pressure on the stick is released so that the plane can get "on the step." Various tricks for take-off under unusual conditions can be easily demonstrated by a competent seaplane instructor.

The take-off run for a seaplane is much longer than for a landplane of corresponding power, and the pilot should therefore make sure that he has adequate space before attempting take-off. If the take-off area contains debris or is not commonly used for seaplane operations, it is good practice to make a careful check by taxiing downwind the entire length of the "runway" to observe obstructions and ascertain that the path is clear for take-off.

In landing a seaplane, it is important to select the correct type of landing for varying water conditions. If the water is rough, the plane should be brought in as slowly as possible in a nose-high attitude. This will avoid the possibility of having the floats nose into a wave or bounce the plane into a dangerous stall.

Under normal conditions on reasonably calm water, a semistall landing is preferable.

On very smooth water, a landing may be made which corresponds to the wheel landing of a landplane. The plane is brought down with excess speed and set "on the step" in full planing position. This requires considerable skill on the part of the pilot to avoid a tendency of the plane to nose over.

Glassy water presents the most critical condition for landing. When the water is perfectly smooth without ripples, a pilot cannot judge his distance from the surface except by reference to objects along the shore or floating in the water. The safest way to make a landing on glassy water is to approach in a shallow glide with partial power, holding the nose well above the horizon. This attitude should be maintained until the floats contact the water, when power should be cut and the stick moved fully back.

A seaplane pilot has the advantage of a continuous runway beneath him, on which he may land at any time. However, floating or partially submerged objects present sufficient hazard that it is wise to fly low over proposed landing space to observe obstructions before landing on unfamiliar areas. Landings on rough water should be avoided whenever possible. Usually a sheltered area can be found which may be safer even if it involves landing slightly crosswind.

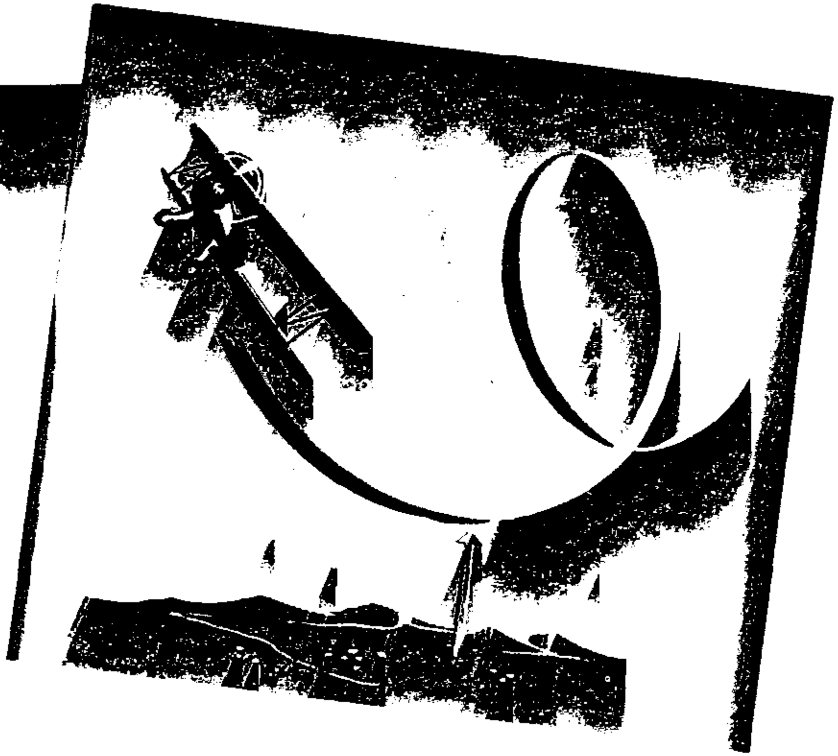
Emergency landings may be made on land with very little hazard. The correct procedure is to select a grassy field and glide to a normal landing, with the nose held slightly above the horizon at the time of contact. If the surface is smooth such landings can be made with little chance of danger to the floats or airplane.

General Maintenance

Inspection plates on the floats should be removed occasionally and the interior checked for evidence of corrosion or leakage. Before every flight the pilot should glance at the position of the floats in the water to note whether they are sitting lower than usual. Such a condition would, of course, indicate the possibility of leakage. A take-off should never be attempted when the floats contain water.

A seaplane flown from salt water should be washed with fresh water at the end of each day's flying to remove deposits of salt which would otherwise cause deterioration of the fabric and corrosion of the metal parts.

Safety in Flight



The modern airplane is structurally and aerodynamically safe for normal flying, just as an automobile is safe for normal driving. The appalling toll of highway accidents is not due to faulty mechanism or dangerous characteristics of the automobile, but to indifference and foolhardiness on the part of automobile drivers. Likewise, most of the accidents involving airplanes cannot be attributed to dangerous characteristics in the airplane itself, but to "pilot error," which could be avoided by the exercise of reasonable skill and judgment.

Nearly all accidents, whether on the highway or in the air, are caused primarily by the human elements of incompetence and carelessness. Statistics on automobile accidents show that drivers fall into two distinct groups—the "accident prone" drivers who are frequently and persistently involved in accidents, and the "safe" drivers who make it a point to avoid situations in which an accident might occur.

The "accident prone" drivers usually are extremely aggressive or extremely shy, overconfident or timid, exhibitionists or day dreamers. They are likely to be mentally immature or lacking in well-rounded personalities. "Safe" drivers, on the other hand, are well-balanced individuals, who respect the rights of others, have the proper degree of self-confidence, and remain constantly alert.

Two Types of Pilots

Airplane pilots, like automobile drivers, fall into the same classifications. The "safe pilot" deliberately avoids dangerous situations, anticipates difficulties, and is prepared to take proper action when necessary. The "accident-prone pilot" usually fails to recognize dangers. Upon being confronted with an unexpected difficulty, he generally reacts slowly and incorrectly or violently and haphazardly.

This is why a safe pilot seems to have a "magic touch" which enables him to fly hundreds or thousands of hours without accident; while an accident-prone pilot, flying the same types of airplanes under similar conditions, will experience a constant succession of accidents, frequently culminating in one which puts an end to his flying.

This chapter presents specific suggestions. They will help you avoid the epitaph frequently appearing in the accident reports: "This fatality is attributed to 'pilot error'."

If you enjoy acrobatics, there is no reason why you should not indulge to your complete satisfaction. Acrobatics properly performed are no more dangerous than cross-country flights. However, you will want to take certain precautions:

1. Be sure that your airplane is designed for acrobatic maneuvers and is in perfect condition.
2. Observe carefully all limitations of speed and weight. Maneuvers which are safe when load and speed are not in excess of the specified limits become very dangerous at speeds or weights over the limits.
3. Don't try new maneuvers without first getting adequate instruction from a competent flight instructor.
4. Keep constant check to be sure that no other airplanes are in your immediate vicinity.
5. Wear a parachute and recheck your safety belt—"just in case."
6. ALWAYS ATTAIN ADEQUATE ALTITUDE before beginning a maneuver. If you make a practice of having a few thousand feet of excess altitude at the completion of the maneuver, you will be able to correct for misjudgment or unexpected situations without imposing excessive strain on the airplane or entering a series of progressive (successive) stalls, or colliding with the ground.

Low-Altitude Maneuvers

Accident records show that about nine out of every ten fatalities and serious injuries are caused by maneuvers performed at low altitude.

Circling

Many of these accidents occur during turns when the pilot's attention is diverted to some person or object on the ground. A slight increase in bank may initiate a steep spiral; a subconscious backward pressure on the controls may promote a stall. Neither of these conditions is dangerous when there is sufficient altitude for recovery, but at low altitude and especially at slow speed the pilot may not be able to make the necessary correction before the airplane strikes the ground.

If you will make all low-altitude turns with a shallow bank and adequate speed, you will eliminate a very frequent cause of fatal accidents.

Stunting

Nearly every pilot, some time in his career, feels the urge to demonstrate his skill to friends on the ground. The exhibition generally takes the form of diving and zooming, often combined with a perverted kind of chandelle, and frequently ending in a stall, semispin, and nose-first contact with the ground. Apparently no amount of warning can serve to discourage a pilot who becomes obsessed with the show-off spirit. The only practical suggestion for your safety is that when you "feel the urge" you might request your earth-bound friends to accompany you while you demonstrate your skill in such maneuvers performed at safe altitude. Should they refuse, you may regard them with scorn as being undeserving of an exhibition of superb flying technique, and express your disdain by remaining aloof and aloft.

Hedge-Hopping

"Hedge-hopping" or "grass-cutting" is another kind of low-altitude flying which produces many fatalities. Rough air near the ground, restricted visibility, or slight inattention may cause momentary loss of control or misjudgment, resulting in a subsequent stall or collision with trees, telephone wires, high-tension lines, and sometimes even hills or buildings.

Forced Landings

It is difficult to give specific advice which will apply to the various conditions under which forced landings may occur. The best precaution is to fly at an altitude which will afford you a reasonable choice of landing area and enable you to establish a normal glide and maneuver into the best available field. When you have selected the field, you should concentrate upon getting into *that* field rather than to change your mind and attempt to reach another field which may momentarily appear more desirable. Above all, keep the airplane under control. If you bring your airplane to the ground in normal landing attitude, your chances of escape without injury are far greater than if you attempt to stretch your glide or maneuver too abruptly, incurring the risk of a stall and vertical dive into the ground.

Downwind Turns

Perhaps the most treacherous condition of flight is a downwind turn at low altitude. Any turn at low altitude has some element of danger, but a downwind turn carries additional hazards for the following reasons:

1. Air near the ground tends to be rough and gusty because of obstructions such as trees and buildings. When the airplane is banked in a downwind turn, the wing nearer the ground may encounter a temporary lull at the same moment that the other wing receives the full force of a gust. That condition causes a sudden over-banking tendency which might prove disastrous when the airplane is flying at slow speed.

2. When flying downwind a pilot may subconsciously interpret the increase in ground speed as an increase in air speed. He may, consequently, allow his air speed to approach stalling speed, or try to climb at too steep an angle.

3. Engine failure in a low-altitude downwind turn usually forces the pilot to make a difficult downwind landing.

Appendix

The table on the next page gives approximate figures for take-off ground-run and rate-of-climb at temperatures from 0° F. to 100° F., and pressure altitudes from sea level to 7,000 feet. They do not take into consideration the extra performance which may be obtained from use of constant-speed or controllable-pitch propellers, supercharged or altitude engines, flaps, retractable gear, etc., which may permit a shorter take-off and faster rate-of-climb. The figures used are merely typical and may not be exact for any given airplane. However, they do represent an accurate measurement in terms of increase or decrease in performance.

The altitude used in the tables is "pressure altitude" which may be determined by setting the altimeter to the "standard atmosphere" of 29.92 and reading the altitude shown on the dial. The power-loading and wing-loading of any aircraft can usually be obtained from the manufacturer's specifications. Power-loading is the gross weight of the airplane divided by the rated horsepower of the engine. Wing-loading is the gross weight of the aircraft divided by square feet of wing area (on nontapered wings the product of the span times the chord).

How To Use the Table

(1) Select the columns corresponding to the wing-loading and power-loading of the airplane (if the values fall between those listed, select the next higher value). (2) Set the altimeter scale at 29.92, read the altitude indicated, and select the altitude grouping for the nearest 1,000 feet. (3) Select the temperature nearest the outside air temperature. (4) Opposite the temperature, in the appropriate columns, read the take-off distance in feet required on a hard-surfaced runway with no wind and the rate-of-climb in feet per minute.

For example, an airplane with a wing-loading of 10 and a power-loading of 15, taking off from a field at which the altimeter showed a reading of 4,000 feet (when the scale is set to 29.92), with air temperature 80° F., would require a take-off ground-run of approximately 1,135 feet. The rate-of-climb would be 700 feet a minute.

TAKE-OFF DISTANCE AND RATE OF CLIMB

(CALCULATIONS SHOWN HERE APPLY TO SEA LEVEL ENGINES AND FIXED PITCH PROPELLERS)

Altimeter Reading		TAKE-OFF GROUND RUN (Feet)												RATE OF CLIMB (Feet per minute)											
	Wing Loading	5				10				15				5				10				15			
	Power Loading	15	20	25	30	10	15	20	25	5	10	15	20	15	20	25	30	10	15	20	25	5	10	15	20
	Temperature																								
Sea Level	0	173	246	330	429	296	486	719	1,000	234	518	872	1,321	1,245	838	593	430	1,925	1,108	703	456	4,265	1,825	1,013	607
	20	189	270	366	476	322	530	787	1,110	254	566	957	1,470	1,203	810	564	405	1,862	1,064	668	427	4,160	1,765	966	570
	40	207	298	405	530	354	589	877	1,250	277	620	1,058	1,625	1,165	775	538	384	1,805	1,022	635	398	4,055	1,706	923	534
	60	226	326	446	589	384	641	965	1,390	301	677	1,160	1,808	1,125	745	513	360	1,750	981	600	369	3,950	1,650	880	500
	80	252	352	493	655	419	702	1,062	1,540	328	741	1,282	2,018	1,088	715	488	338	1,697	941	567	341	3,850	1,594	840	466
	100	270	392	541	720	457	768	1,170	1,710	354	802	1,400	2,215	1,050	686	464	316	1,643	903	538	305	3,750	1,536	800	430
1,000	0	193	276	374	489	327	540	804	1,141	256	570	967	1,487	1,183	791	553	396	1,830	1,043	652	414	4,090	1,734	945	554
	20	211	304	413	541	360	600	899	1,279	282	633	1,079	1,661	1,143	762	526	372	1,773	1,002	617	385	3,990	1,673	902	518
	40	232	342	459	605	391	656	990	1,426	306	690	1,187	1,853	1,104	728	500	350	1,717	960	585	355	3,890	1,616	860	483
	60	253	368	503	670	429	720	1,092	1,595	334	758	1,312	2,065	1,067	698	475	327	1,662	920	551	328	3,790	1,560	818	448
	80	276	401	554	740	466	790	1,210	1,770	361	825	1,442	2,300	1,030	669	450	304	1,611	881	518	300	3,690	1,505	777	415
	100	299	439	610	821	506	863	1,332	2,329	391	863	1,579	2,550	994	640	425	283	1,558	842	488	273	3,590	1,450	737	380
2,000	0	212	304	415	545	370	600	898	1,290	282	631	1,080	1,670	1,122	743	514	362	1,740	981	602	373	3,920	1,640	881	502
	20	232	335	460	606	393	660	990	1,440	305	690	1,190	1,860	1,083	714	487	338	1,683	940	567	344	3,820	1,582	838	467
	40	252	370	510	677	430	725	1,111	1,662	333	755	1,310	2,080	1,045	682	461	316	1,628	900	535	313	3,720	1,525	796	431
	60	278	407	563	755	472	802	1,231	1,820	363	830	1,455	2,330	1,008	652	437	293	1,575	859	502	287	3,620	1,470	754	397
	80	306	449	625	844	516	882	1,370	2,042	397	914	1,620	2,620	973	624	413	272	1,525	820	470	259	3,525	1,418	714	364
	100	330	487	684	930	556	956	1,492	2,260	426	990	1,760	2,890	936	596	388	250	1,474	782	440	233	3,430	1,363	673	330
3,000	0	234	340	465	615	396	666	1,010	1,460	309	700	1,210	1,900	1,060	695	474	328	1,650	918	552	331	3,745	1,548	816	450
	20	258	378	520	695	432	742	1,140	1,660	339	771	1,350	2,150	1,023	666	448	304	1,594	876	517	301	3,650	1,490	773	415
	40	285	414	575	771	481	820	1,260	1,865	369	847	1,490	2,380	987	636	422	282	1,540	837	485	272	3,550	1,434	731	380
	60	310	455	635	860	523	896	1,390	2,080	400	928	1,640	2,675	950	606	400	259	1,488	798	453	245	3,455	1,380	691	346
	80	338	499	700	953	569	980	1,538	2,340	435	1,010	1,808	2,982	915	578	375	239	1,439	759	421	218	3,360	1,329	650	313
	100	368	544	772	1,063	615	1,071	1,695	2,620	470	1,100	1,990	3,320	880	550	350	217	1,390	723	392	193	3,270	1,278	611	280
4,000	0	266	390	538	722	451	765	1,180	1,739	349	765	1,400	2,245	1,000	647	435	293	1,558	854	500	288	3,570	1,456	751	397
	20	294	431	599	797	497	849	1,320	1,965	382	880	1,560	2,535	963	618	408	270	1,504	813	466	258	3,475	1,400	707	363
	40	322	477	666	890	545	939	1,471	2,225	417	968	1,730	2,860	927	588	383	248	1,450	774	434	230	3,380	1,343	687	328
	60	351	521	735	1,010	591	1,027	1,623	2,490	452	1,020	1,902	3,180	892	560	360	226	1,400	735	404	203	3,290	1,292	626	294
	80	386	575	815	1,140	647	1,135	1,810	2,925	492	1,160	2,120	3,600	857	532	338	205	1,352	700	372	176	3,195	1,241	587	261
	100	419	630	903	1,268	706	1,250	2,020	3,210	532	1,262	2,340	4,040	822	504	313	184	1,304	660	343	151	3,105	1,190	549	230
5,000	0	293	430	601	811	495	848	1,320	1,980	380	876	1,550	2,520	938	600	395	258	1,466	790	449	247	3,400	1,364	686	345
	20	324	477	670	915	546	943	1,480	2,250	417	932	1,735	2,860	902	570	370	236	1,414	750	416	216	3,305	1,306	643	310
	40	354	525	747	1,022	595	1,040	1,646	2,558	454	1,060	1,997	3,200	867	542	345	214	1,362	711	385	169	3,210	1,253	603	277
	60	387	581	834	1,151	650	1,141	1,843	2,920	491	1,160	2,110	3,605	833	514	322	193	1,313	673	354	162	3,125	1,202	562	243
	80	421	639	920	1,283	710	1,252	2,050	3,200	536	1,270	2,350	4,090	800	486	300	172	1,266	638	323	136	3,030	1,153	523	210
	100	456	694	1,010	1,420	768	1,363	2,260	3,682	576	1,380	2,565	4,550	764	460	275	151	1,220	602	293	110	2,945	1,105	485	178
6,000	0	326	484	681	930	550	950	1,502	2,280	421	983	1,833	2,820	876	552	355	224	1,375	726	400	204	3,230	1,272	620	293
	20	359	539	758	1,048	600	1,052	1,682	2,590	458	1,073	1,953	3,310	842	523	330	202	1,324	686	367	174	3,130	1,215	578	259
	40	397	595	850	1,183	647	1,173	1,900	2,990	502	1,189	2,184	3,760	807	495	306	180	1,273	648	335	147	3,040	1,162	538	224
	60	431	655	944	1,327	727	1,286	2,100	3,400	546	1,308	2,380	4,250	773	467	283	158	1,226	611	305	121	2,955	1,113	500	192
	80	471	722	1,048	1,500	787	1,415	2,360	3,860	590	1,420	2,675	4,790	743	440	262	139	1,180	576	274	95	2,870	1,066	460	160
	100	513	789	1,122	1,680	859	1,542	2,620	4,430	641	1,559	2,982	5,450	707	414	238	118	1,135	541	245	70	2,785	1,020	423	128
7,000	0	366	545	776	1,075	615	1,077	1,721	2,685	467	1,100	2,000	3,400	817	505	318	192	1,287	664	349	164	3,060	1,181	556	242
	20	407	609	872	1,228	684	1,210	1,940	3,080	535	1,250	2,360	4,105	782	475	292	168	1,238	623	318	135	2,965	1,125	515	208
	40	451	685	990	1,412	755	1,347	2,205	3,635	569	1,368	2,560	4,540	748	448	267	147	1,186	576	287	106	2,875	1,074	475	174
	60	490	772	1,092	1,580	815	1,470	2,442	4,100	613	1,486	2,820	5,140	715	422	246	127	1,140	550	258	80	2,795	1,026	437	142
	80	541	825	1,220	1,790	893	1,623	2,740	4,750	662	1,568	3,120	5,835	684	396	225	107	1,095	518	228	56	2,710	980	400	111
	100	585	910	1,361	2,025	973	1,731	3,181	5,450	720	1,780	3,495	6,750	651	370	202	85	1,052	482	198	31	2,625	935	362	79

References for Further Study

This booklet, as the conciseness of its text indicates, is intended to introduce the reader to the subjects with which it deals and to supplement the teachings of a competent flight instructor.

Additional information on those subjects is available in the FAA publications listed below, which may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at the indicated prices.

PATH OF FLIGHT—Explains the fundamentals of navigation in VFR flying. (65¢)

REALM OF FLIGHT—Explains the basic principles of meteorology and offers specific suggestions for interpretation of weather data and weather conditions encountered in flight. (75¢)

PRIVATE PILOT'S HANDBOOK OF AERONAUTICAL KNOWLEDGE—This booklet, heavily illustrated, contains the aeronautical knowledge required of the private pilot.

AIRMAN'S GUIDE—Issued every two weeks. (Subscription price, $7.00 a year; $3.50 additional for foreign mailing. Prices of individual copies vary depending on size)

FLIGHT INFORMATION MANUAL—Issued annually with amendments. ($1.50)

PILOTS RADIO HANDBOOK—(75¢)

CIVIL AIR REGULATIONS—Part 43 ($1.25), Part 60 ($1.50)

FEDERAL AVIATION REGULATIONS—Part 61 (30¢)

CIVIL AERONAUTICS BOARD, SAFETY INVESTIGATION REGULATIONS—Part 320 (5¢)

WEATHER SERVICES FOR PILOTS—Describes what information is available, where to get it, and how to get it. (10¢)

In addition to the materials available from the Superintendent of Documents, there are excellent textual materials available from commercial publishers.

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