The Student Pilot's Flight Manual

From First Flight to Pilot Certificate

Based on the original text by

William K. Kershner

11th Edition • Edited by William C. Kershner

PRIVATE AND SPORT PILOTS

The

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AVIATION SUPPLIES & ACADEMICS
NEWCASTLE, WASHINGTON

William K. Kershner began flying in 1945 at the age of fifteen, washing and propping airplanes to earn flying time. By this method he obtained the private, then the commercial and flight instructor certificates, becoming a flight instructor at nineteen. He spent four years as a naval aviator, most of the time as a pilot in a night fighter squadron, both shore and carrier based. He flew nearly three years as a corporation pilot and for four years worked for Piper Aircraft Corporation, demonstrating airplanes to the military, doing experimental flight-testing, and acting as special assistant to William T. Piper, Sr., president of the company. Bill Kershner held a degree in technical journalism from Iowa State University. While at the university he took courses in aerodynamics, performance, and stability and control. He held the airline transport pilot, commercial, and flight and ground instructor certificates and flew airplanes ranging from 40-hp Cubs to jet fighters. He is the author of *The Student Pilot's Flight Manual, The Instrument Flight Manual, The Advanced Pilot's Flight Manual, The Flight Instructor's Manual,* and *The Basic Aerobatic Manual*. Kershner operated an aerobatics school in Sewanee, Tennessee using a Cessna 152 Aerobat. He received the General Aviation Flight Instructor of the Year Award, 1992, at the state, regional and national levels. The Ninety-Nines awarded him the 1994 Award of Merit. In 1998 he was inducted into the Flight Instructor Hall of Fame, in 2002 was installed in the Tennessee Aviation Hall of Fame, and in 2007 was inducted into the International Aerobatic Club Hall of Fame. William K. Kershner died January 8th, 2007.

Editor William C. Kershner received his early flight training from his father, William K. Kershner. He holds Commercial, Flight Instructor and Airline Transport Pilot certificates and has flown 22 types of airplanes, ranging in size from Cessna 150s to Boeing 777s, in his 15,000+ flight hours. He retired from commercial aviation as a 737 check airman and lives near Sewanee, Tennessee, with his wife and younger son.

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William K. Kershner
Illustrated by the Author

Aviation Supplies & Academics, Inc. • 7005 132nd Place SE • Newcastle, WA 98059
Email: asa@asa2fly.com • Internet: www.asa2fly.com

Cover photo: William K. Kershner flies his Cessna 152 Aerobat, N7557L, near his home of Sewanee, Tennessee. This photo was taken by Mike Fizer on March 14th, 2000 for the 2001 AOPA calendar. Dad had over 7,000 separate spins of between 3 and 25 turns in his 22 years teaching aerobatics in this airplane. Two months after his death in January 2007, my son, Jim, and I were honored to deliver 57L to Dulles International Airport for display at the National Air and Space Museum's Steven F. Udvar-Hazy Center. —*William C. Kershner*
Photo credits: Front cover, courtesy of AOPA; photo under Dedication, page v, and Chapter 24 cross-country photos, courtesy of Elizabeth Motlow; start of Part 1 "Before the Flight," Adam Korzekwa/istockphoto; start of Part 2 "Presolo," George Jurasek/istockphoto; start of Part 3 "Postsolo Maneuvers" and Part 6 "Syllabus," Ken Babione/istockphoto; start of Part 4 "Cross Country and Night Flying," photo © Smithsonian Institution, used with permission of National Air and Space Museum; start of Part 5 "The Knowledge and Practical (Flight) Tests," skyf/fotolia.

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Dedication

The 11th Edition of the *Student Pilot's Flight Manual* is dedicated to my parents:

Elizabeth Ann Deyo Kershner 1933-2009

William K. Kershner 1929-2007

Acknowledgments for the Eleventh Edition

Thanks go to my wife Donna for her help and encouragement.

My editors at ASA continued to offer great patience and invaluable advice for this new edition. Donna Webster, designated pilot examiner, helped me get a grasp on the new FAA "Airman Certification Standards."

And my special thanks again go to flight instructor Genie Rae O'Kelley for her help with my aviation career and the careers of so many others.

The acknowledgments for the 1st through 10th Editions are found in the back of the book with the Bibliography.

Preface to the Eleventh Edition

This book is written to cover the fundamentals of lightplane flying, and emphasizes flying skills and knowledge that will cover a wide range of airplane types and sizes. For instance, crosswind landing techniques effective in a Cessna 152 can also work well in a Boeing 777 or Bandeirante turbo prop. And although technology has changed dramatically over the years, the basics of flying and good judgment have not.

This manual is not intended to just help the reader "squeak by" the FAA knowledge (written) test and practical test (flight test or checkride), but to lay a foundation of solid knowledge for use in the everyday process of learning to fly airplanes. Even after thousands of hours in the air, most pilots still learn something on every flight.

The flight maneuvers are written in the probable order of introduction to the student. The spin is included to give the student pilot an idea of what the maneuver entails and the dangers involved in an inadvertent low-altitude spin.

Although this book was originally written for the individual working toward the private pilot certificate, ASEL (airplane, single-engine, land), it includes all the information necessary for the slightly more restrictive sport or recreational pilot certificates. For example, the sport pilot applicant will not require training in emergency instrument flight (Chapter 15) or night flying (Chapter 26). The already certificated pilot can use this book in preparing for the Flight Review (14 CFR 61.56—required every 24 months). Referencing Chapters 27 and 28, along with a review of 14 CFR Parts 61 and 91, will bring the pilot back up to speed on subjects perhaps not touched on in awhile.

You'll notice that technology is not front-and-center in this manual. Although you'll be responsible for basic knowledge of any installed navigation systems, the practical test continues to focus on the basic skills of flying: controlling the airplane, using good judgment in choosing a course of action, and basic navigation using landmarks and a chart. The FAA's "Airman Certification Standards" (FAA-S-ACS-6) is the detailed guide for the "checkride," containing a welcome emphasis on risk management, identifying the hazards to a particular flight, and minimizing them.

This manual is, of necessity, written in general terms, as seen in the (often changing) areas of information and weather services. Because airplanes vary from type to type in the use of flaps, carburetor heat, spin recovery and other procedures, the *Pilot's Operating Handbook* or equivalent source is the final guide for operation of your specific trainer. Of course, all of the performance and navigation charts in this text are for reference and example only.

Pilots should have ready access to a few other important resources. I have found the bare minimum to be the *Aeronautical Information Manual* (AIM), Federal Aviation Regulations (Title 14 of the Code of Federal Regulations), *Aviation Weather Services* (FAA Advisory Circular 00-45), and *Aviation Weather* (AC 00-6A). The *Advanced Pilot's Flight Manual* (Kershner) is a good source for more detail on aerodynamics and for transition to more complex airplane types.

I will welcome any feedback offered on the 11th Edition of *The Student Pilot's Flight Manual*. Please contact me through ASA (email: feedback@asa2fly.com).

Flying is one of mankind's most rewarding and challenging endeavors. Every flight is different and most experienced pilots can tell of wonders they've seen that no ground-bound person will ever know.

William C. Kershner
Sewanee, Tennessee

Part One
Before the Flight

1

1

Starting to Fly

There are many reasons why people want to start flying. Maybe you are a younger person who wants to make it a lifetime career or maybe you are a slightly more senior citizen who always wanted to fly but until now haven't had the money. Whether a man or woman, young or old, you still may have a few butterflies in your stomach while worrying about how you will like it or whether you can do it. That's a natural reaction.

What can you expect as you go through the private pilot training course? You can expect to work hard on most flights and to come down from some flights very tired and wet with perspiration, but with a feeling of having done something worthwhile. After others, you may consider forgetting the whole idea.

Okay, so there will be flights that don't go so well, no matter how well you get along with your instructor. The airplane will seem to have decided that it doesn't want to do what you want it to. The situation gets worse as the flight progresses and you end the session with a feeling that maybe you just aren't cut out to be a pilot. If you have a couple of these in a row, you should consider changing your schedule to early morning instead of later afternoon flights, or vice versa. You may have the idea that everybody but you is going through the course with no strain at all, but every person who's gone through a pilot training course has suffered some "learning plateaus" or has setbacks that can be discouraging.

After you start flying, you may at some point decide that it would be better for your learning process if you changed instructors. This happens with some people and is usually a no-fault situation, so don't worry about a change or two.

It's best if you get your FAA (Federal Aviation Administration) medical examination out of the way very shortly after you begin to fly or, if you think that you might have a problem, get it done before you start the lessons. The local flight instructors can give you names of nearby FAA aviation medical examiners.

How do you choose a flight school? You might visit a few in your area and see which one suits you best. Watch the instructors and students come and go to the airplanes. Are the instructors friendly, showing real interest in the students? There should be pre- and postflight briefings of students. You may not hear any of the details, but you can see that such briefings are happening. Talk to students currently flying at the various schools and get their opinions of the learning situation. One good hint about the quality of maintenance of the training airplanes is how clean they are. Usually an airplane that is clean externally is maintained well internally, though certainly there are exceptions to this.

What about the cost? It's a good idea to have money ahead so that you don't have to lay off and require a lot of reviewing from time to time. Some flight schools give a discount if you pay for several hours ahead of time.

You are about to set out on a very rewarding experience; for an overall look at flight training and future flying you might read the following.

The Big Three

As you go through any flight program, particularly in a military flight program, you will hear three terms used many times: *headwork, air discipline,* and *attitude toward flying*. You may be the smoothest pilot since airplanes were invented, but without having a good grip on these requirements, you won't last long.

Headwork

For any pilot, private or professional, the most important thing is good headwork. Nobody cares if you slip or skid a little or maybe every once in a while land a mite harder than usual, but if you don't use your head—if you fly into bad weather or forget to check the fuel and have to land in a plowed field—you'll find

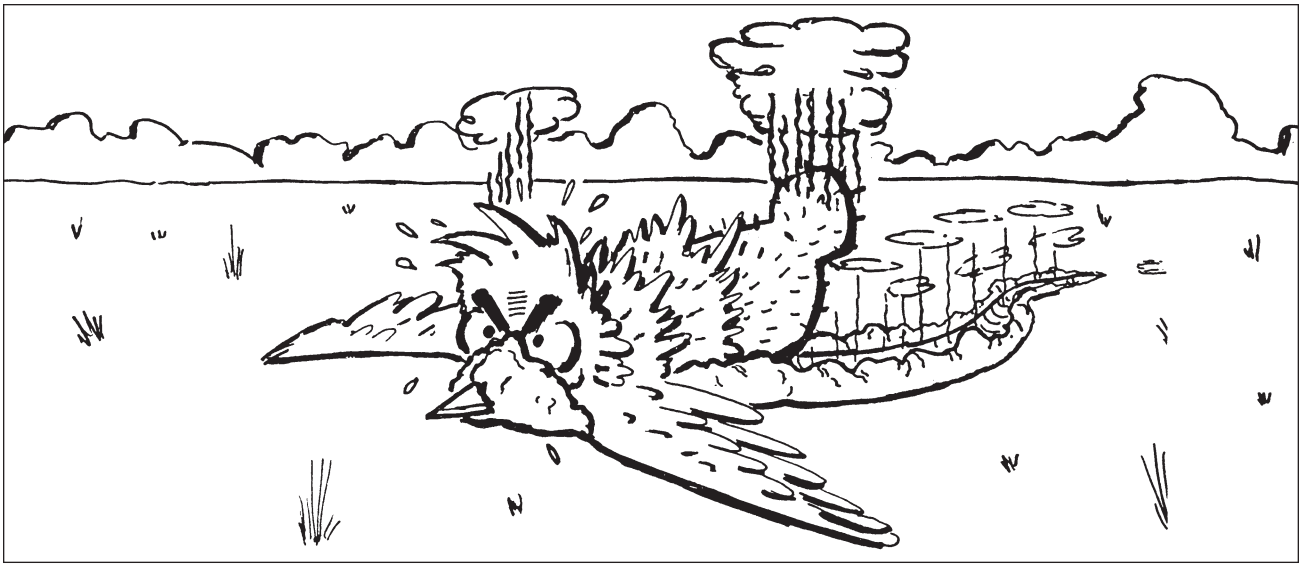


Figure 1-1. Headwork is remembering to put the landing gear down.

people avoiding you. Later, as you progress in aviation and lead flights or fly passengers, it's a lot more comfortable for all concerned if they know you are a person who uses your head in flying. So as the sign says—THILK, er, think.

Air Discipline

This is a broad term, but generally it means having control of the aircraft and yourself at all times. Are you a precise pilot or do you wander around during maneuvers? Do you see a sports car and decide to buzz it? Air discipline is difficult at times. It's mighty tough not to fly over that good-looking member of the opposite sex who happens to be sunbathing right where you are doing S-turns across the road—but be strong!

More seriously, air discipline is knowing, and flying by, your own limitations. This means, for instance, canceling for bad weather and not risking your life and your passengers' lives. It also means honestly analyzing your flying faults and doing something about them. In short, air discipline means a mature approach to flying.

Attitude

A good attitude toward flying is important. Most instructors will go all out to help someone who's really trying. Many an instructor's favorite story is about ol' Joe Blow who was pretty terrible at first, but who kept at it until he got the word, and is now flying rockets for Trans-Galaxy Airlines. With a good attitude you will get plenty of help from everybody. More students have failed in flying because of poor headwork and attitude than for any other reason. This doesn't imply "apple polishing." It does mean that you are interested in flying and study more about it than is required by law.

2

The Airplane and How It Flies

The Four Forces

Four forces act on an airplane in flight: *lift, thrust, drag,* and *weight* (Figure 2-1).

Lift

Lift is a force exerted by the wings. (Lift may also be exerted by the fuselage or other components, but at this point it would be best just to discuss the major source of the airplane's lift, the wings.) It is a force created by the "airfoil," the cross-sectional shape of the wing being moved through the air or, as in a wind tunnel, the air being moved past the wing. The result is the same in both cases. The "relative wind" (wind moving in relation to the wing and airplane) is a big factor in producing lift, although not the only one (Figure 2-2).

Lift is always considered to be acting perpendicularly both to the wingspan and to the relative wind (Figure 2-3). The reason for this consideration will be shown later as you are introduced to the various maneuvers.

As the wing moves through the air, either in gliding or powered flight, lift is produced. How lift is produced can probably be explained most simply by Bernoulli's theorem, which briefly puts it this way: "The faster a fluid moves past an object, the less sidewise pressure is exerted on the body by the fluid." The fluid in this case is air; the body is an airfoil. Take a look at Figure 2-4, which shows the relative wind approaching an airfoil, all neatly lined up in position 1. As it moves past the airfoil (or as the airfoil moves past it—take your choice), things begin to happen, as shown by the subsequent numbers.

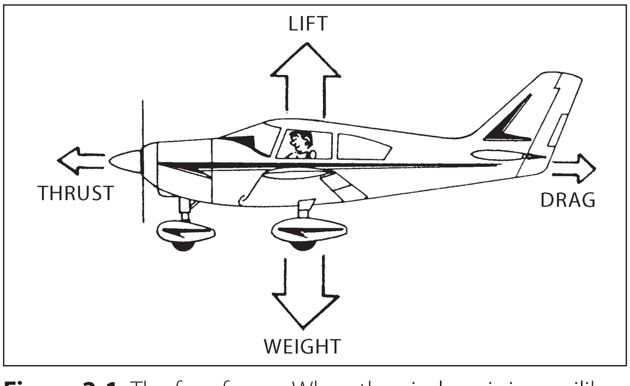


Figure 2-1. The four forces. When the airplane is in equilibrium in straight and level cruising flight, the forces acting fore and aft (thrust and drag) are equal, as are those acting at 90° to the flight path (lift and weight, or its components).

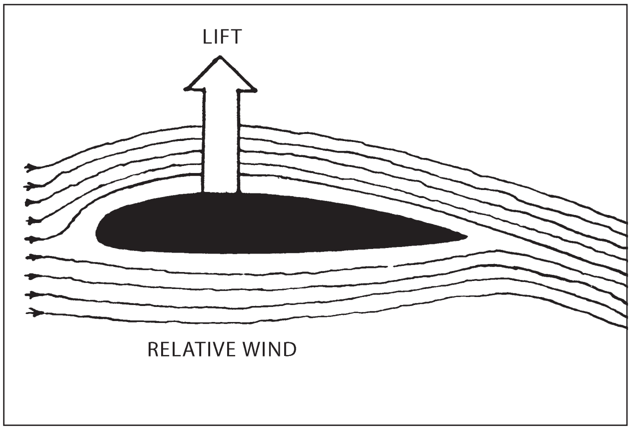


Figure 2-2. The airfoil.

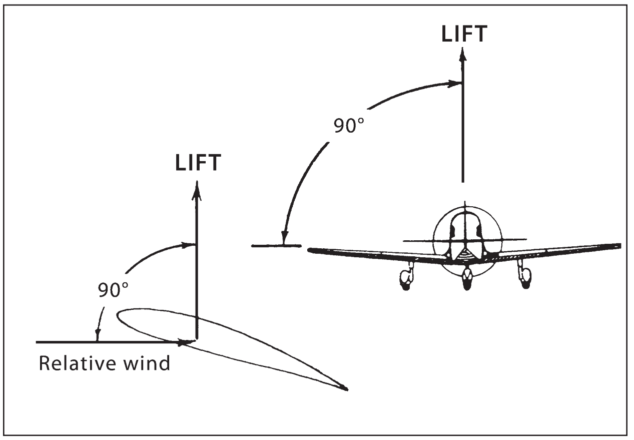


Figure 2-3. Lift acts perpendicular to the relative wind and wingspan.

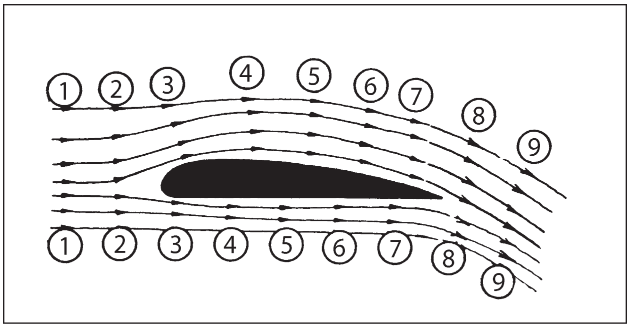


Figure 2-4. Airflow past the airfoil.

The distance that the air must travel over the top is greater than that under the bottom. As the air moves over this greater distance, it speeds up in an apparent attempt to reestablish equilibrium at the rear (trailing edge) of the airfoil. (Don't worry, equilibrium *won't* be reestablished.) Because of this extra speed, the air exerts less sidewise pressure on the top surface of the airfoil than on the bottom, and lift is produced. The pressure on the bottom of the airfoil is normally increased also and you can think that, as an average, this contributes about 25 percent of the lift; this percentage varies with "angle of attack" (Figure 2-5).

Some people say, "Sure, I understand what makes a plane fly. There's a vacuum on top of the wing that holds the airplane up." Let's see about that statement.

The standard sea level air pressure is 14.7 pounds per square inch (psi), or 2,116 pounds per square foot (psf). As an example, suppose an airplane weighs 2,000 pounds, has a wing area of 200 square feet, and is in level flight at sea level. (The wing area is that area you would see by looking directly down on the wing.) This means that for it to fly level (lift = weight) each square foot of wing must support 10 pounds of weight, or the wing loading is 10 pounds psf (2,000 divided by 200). Better expressed: There would have to be a difference in pressure of 10 pounds psf between the upper surface and the lower surface. This 10 psf figure is an average; on some portions of the wing the difference will be greater, on others, less. Both surfaces of the wing can have a reduced sidewise pressure under certain conditions. However, the pressure on top still must average 10 psf less than that on the bottom to meet our requirements of level flight for the airplane mentioned. The sea level pressure is 2,116 pounds psf, and all that is needed is an average difference of 10 psf for the airplane to fly.

Assume for the sake of argument that, in this case, the 10 psf is obtained by an *increase* of 2.5 psf on the bottom surface and a *decrease* of 7.5 psf on the top (which gives a total difference of 10 psf). The top surface pressure varies from sea level pressure by 7.5 psf. Compared to the 2,116 psf of the air around it, this is certainly a long way from a vacuum, but it produces flight!

Note in Figures 2-2 and 2-4 that the airflow is deflected downward as it passes the wing. Newton's law, "For every action there is an equal and opposite reaction," also applies here. The wing deflects the airflow downward with a reaction of the airplane being sustained in flight. This can be easily seen by examining how a helicopter flies. Some engineers prefer Newton's law over Bernoulli's theorem. But the air *does* increase its velocity over the top of the wing (lowering the pressure), and the downwash also occurs. The downwash idea and how it affects the forces on the horizontal tail will be covered in Chapters 17 and 23.

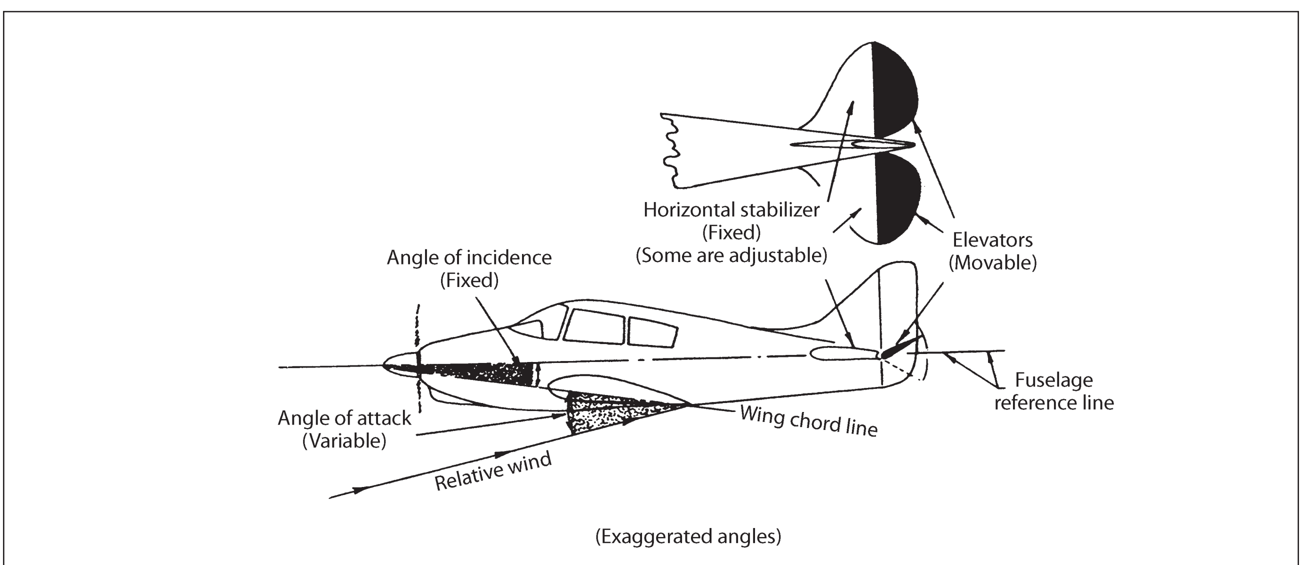


Figure 2-5. Nomenclature.

Angle of Attack

The angle of attack is the angle between the relative wind and the chord line of the airfoil. Don't confuse the angle of attack with the angle of *incidence*. The angle of *incidence* is the fixed angle between the wing chord line and the reference line of the fuselage. You'd better take a look at Figure 2-5 before this gets too confusing.

The pilot controls angle of attack with the elevators (Figure 2-5). By easing back on the control wheel (or stick) the elevator is moved "up" (assuming the airplane is right side up). The force of the relative wind moves the tail down, and because the wings are rigidly attached to the fuselage (you hope), they are rotated to a new angle with respect to the relative wind, or new *angle of attack*. At this new angle of attack the apparent curvature of the airfoil is greater, and for a very short period, lift is increased. But because of the higher angle of attack more drag is produced, the airplane slows, and equilibrium exists again. (More about drag later.)

If you get too eager to climb and *mistakenly* believe that the reason an airplane climbs is because of an "excess" of lift (and so keep increasing the angle of attack), you could find that you have made a mistake. As you increase the angle of attack, the airplane slows and attempts to reestablish equilibrium, so you continue to increase it in hopes of getting an "excess" of lift for more climb. You may make the angle of attack so great that the air can no longer flow smoothly over the wing, and the airplane "stalls" (Figure 2-6).

It's not like a car stalling, in which case the engine stops; the airplane stall is a situation where the lift has broken down and the wing, in effect, is no longer doing its job of supporting the airplane in the usual manner. (The engine may be humming like a top throughout the stall.) There is still some lift, but not enough to support the airplane. You have forced the airplane away from the balanced situation you (and the airplane) want to maintain. For the airplane to recover from a stall, you must decrease the angle of attack so that smooth flow again occurs. In other words, point the plane where it's going! This is done with the elevators, the angle of attack, (and speed) control (Figure 2-5). For most lightplane airfoils, the stalling angle of attack is in the neighborhood of 15°. Stalls will be covered more thoroughly in Chapters 12 and 14.

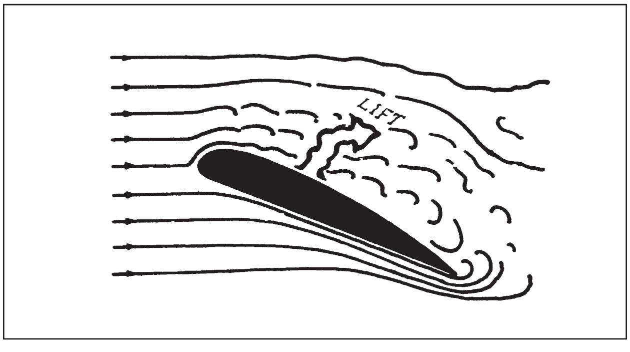


Figure 2-6. The stall.

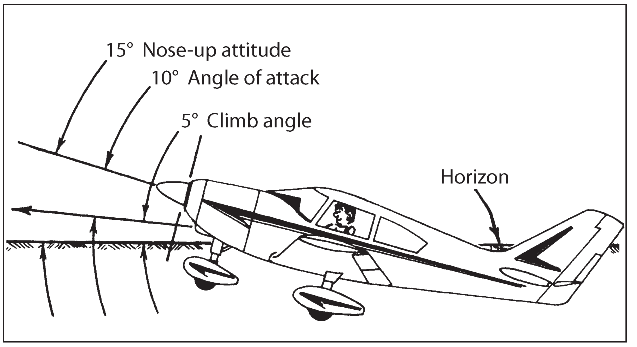


Figure 2-7. Pitch attitude, climb angle (flight path), and angle of attack.

At first, the student is also confused concerning the *angle of attack* and airplane *attitude*. The attitude is how the plane looks in relation to the horizon. In Figure 2-7 the plane's attitude is 15° nose up, but it's climbing at an angle of 5°, so the angle of attack is only 10°.

In a slow glide the nose attitude may be approximately level and the angle of attack close to that of the stall. Later in your flying, you'll be introduced to the attitude of the wings (wing-down attitude, etc.), but for now only nose attitudes are of interest.

The coefficient of lift is a term used to denote the relative amounts of lift at various angles of attack for an airfoil. The plot of the coefficient of lift versus the angle of attack is a straight line, increasing with an increase in the angle of attack until the stalling angle is reached (Figure 2-8).

Lift depends on a combination of several factors. The equation for lift is:

$$L = C_L S \frac{\rho}{2} V^2, \text{ or } L = C_L \times S \times \frac{\rho}{2} \times V^2$$

where L = lift, in pounds

C_L = coefficient of lift (varies with the type of airfoil used and the angle of attack). The coefficient of lift, C_L, is a dimensionless product and gives a *relative* look at the wings' action. The statement may be made in groundschool that, "At this angle of attack, the coefficient of lift is point five (0.5)." Point five what? "Just point five, and it's one-half of the C_L at one point zero (1.0)." Just take it as the relative effectiveness of the airfoils at a given angle of attack. Later, the coefficient of *drag* will be discussed.

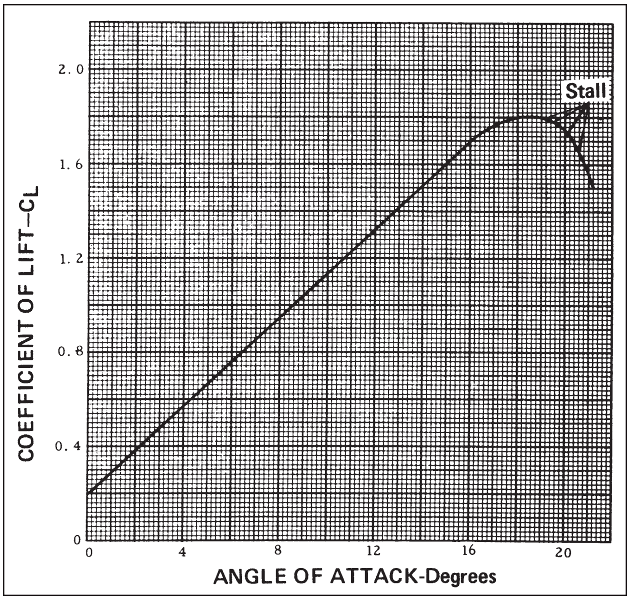


Figure 2-8. Relative lift increases with angle of attack until the stall angle is reached.

S = wing area in square feet

$\frac{\rho}{2}$ = air density (ρ) divided by 2. Rho (ρ) is air density, which for standard sea level conditions is 0.002378 slugs per cubic foot. If you want to know the mass of an object in slugs, divide the weight by the acceleration of gravity, or 32.2. (The acceleration caused by gravity is 32.2 feet per second per second at the earth's surface.)

V^2 = velocity in feet per second squared

When you fly an airplane, you'll be working with a combination of C_L and velocity; but let's talk in pilot terms and say that you'll be working with a combination of angle of attack and airspeed. So lift depends on angle of attack, airspeed, wing area, and air density. For straight and level flight, lift equals weight. Assuming that your airplane weighs 2,000 pounds, 2,000 pounds of lift is required to maintain level flight. This means that the combination of the above factors must equal that value. The wing area (S) is fixed, and the air density (ρ) is fixed for any one time and altitude. Then C_L (angle of attack) and velocity (airspeed) can be worked in various combinations to maintain the 2,000 pounds of lift required. Flying at a low airspeed requires a high angle of attack, and vice versa. As the pilot you will control angle of attack and, by doing so, control the airspeed. You'll use power (or lack of power) with your chosen airspeed to obtain the desired performance.

While the factors of lift are being discussed, it might be well to say a little more about air density (ρ). The air density decreases with increased altitude and/or temperature increase. Because of the decreased air density, airplanes require more runway for takeoff at airports of high elevation or on hot days. You can see in the lift equation that if the air is less dense, the airplane will have to move faster through the air in order to get the required value of lift for flight—and this takes more runway. (The airspeed mentioned is called "true airspeed" and will be discussed in more detail in Chapter 3.) Not only is the lift of the wing affected, but the less dense air results in less power developed within the engine. Since the propeller is nothing more than a rotating airfoil, it also loses "lift" (or, more properly, "thrust"). Taking off at high elevations or high temperatures can be a losing proposition, as some pilots have discovered after ignoring these factors and running out of runway.

Interestingly enough, you will find that lift tends to remain at an almost constant value during climbs, glides, or straight and level flight. *Don't* start off by thinking that the airplane glides because of decreased lift or climbs because of excess lift. *It just isn't so.*

Thrust

Thrust is the second of the four forces and is furnished by a propeller or jet. The propeller is of principal interest to you at this point, however.

The theory of propellers is quite complicated, but Newton's "equal and opposite reaction" idea can be stated here. *The propeller takes a large mass of air and accelerates it rearward, resulting in the equal and opposite reaction of the plane moving forward.*

Maybe it's time a few terms such as "force" and "power" should be cleared up. Thrust is a *force* and, like the other three forces, is measured in pounds. A *force* can be defined as a tension, pressure, or weight. You don't necessarily have to move anything; you can exert force against a very heavy object and nothing moves. Or you can exert a force against a smaller object and it moves. When an object having force exerted upon it moves, *work* has been done.

Work, from an engineering point of view, is simply a measure of *force* times *distance*. And while at the end of a day of pushing against a brick wall or trying to lift a safe that won't budge, you feel tired, actually you've done no *work* at all. If you lift a 550-pound safe 1 foot off the floor, you'll have done 550 foot-pounds of *work* (and no doubt strained yourself in the bargain). If you lift a 50-pound weight to a height of 11 feet, you'll have done the same *work* whether you take all day or 1 second to do it—but you won't be developing as much *power* by taking all day. So the *power* used in lifting that 50 pounds up 11 feet, or 550 pounds up 1 foot, in 1 second would be expressed as:

Power = 550 foot-pounds per second

Obviously, this is leading somewhere, and you know that the most common measurement for power is the term "horsepower." One horsepower is equal to a power of 550 foot-pounds per second, or 33,000 foot-pounds per minute (60 seconds × 550). Whether the average horse of today can actually do this is not known, and unfortunately nobody really seems to care.

The airplane engine develops horsepower within its cylinders and, by rotating a propeller, exerts thrust. In straight and level, unaccelerated, cruising flight the thrust exerted (pounds) is considered to equal the drag (pounds) of the airplane.

You will hear a couple of terms concerning horsepower:

Brake horsepower—the horsepower developed at the crankshaft. In earlier times this was measured at the crankshaft by a braking system or absorption dynamometer known as a "prony brake." *Shaft* horsepower means the same thing. Your airplane engine is always rated in brake horsepower, or the power produced at the crankshaft. Brake horsepower and engine ratings will be covered more thoroughly in Chapter 23.

Thrust horsepower—the horsepower developed by the propeller in moving the airplane through the air. Some power is lost because the propeller is not 100 percent efficient, and for round figures, you can say that the propeller is at best about 85 percent efficient (the efficiency of the fixed-pitch propeller varies with airspeed). The thrust horsepower developed, for instance, will be only up to about 85 percent of the brake horsepower.

If you are mathematically minded, you might be interested in knowing that the equation for thrust horsepower (THP) is: THP = TV ÷ 550, where T is thrust (pounds) and V is velocity (feet per second) of the airplane. Remember that a *force* times a *distance* equals *work*, and when this is divided by time, *power* is found. In the equation above, *thrust* is the force, and velocity can be considered as being distance divided by time, so that TV (T × V) is power in foot-pounds per second. Knowing that 1 horsepower is 550 footpounds per second, the power (TV) is divided by 550 and the result would give the horsepower being developed—in this case, *thrust horsepower*. (*See* Chapter 9.) THP = TV mph ÷ 375, or TV knots ÷ 325 (more about "knots" later).

For light trainers with fixed-pitch propellers, a measure of the power (brake horsepower) being used is indicated on the airplane's tachometer in rpm (revolutions per minute). The engine power is controlled by the throttle. For more power the throttle is pushed forward or "opened"; for less power it is moved back or "closed." You'll use the throttle to establish certain rpm (power) settings for cruise, climb, and other flight requirements.

Torque

Because the propeller is a rotating airfoil, certain side effects are encountered. The "lift" force of the propeller is the thrust used by the airplane. The propeller also has a drag force. This force acts in a sidewise direction (parallel to the wing span or perpendicular to the fuselage reference line).

The propeller rotates clockwise as seen from the cockpit, causing a rotating mass of air to be accelerated toward the tail of the airplane. This air mass strikes the left side of the vertical stabilizer and rudder. This air mass, called "slipstream" or "propwash," causes the airplane to veer or "yaw" to the left. Right rudder must therefore be applied to hold the airplane on a straight track (Figure 2-9). This reaction increases with power, so it is most critical during the takeoff and climb portion of the flight. The slipstream effect is the biggest factor of torque for the single-engine airplane.

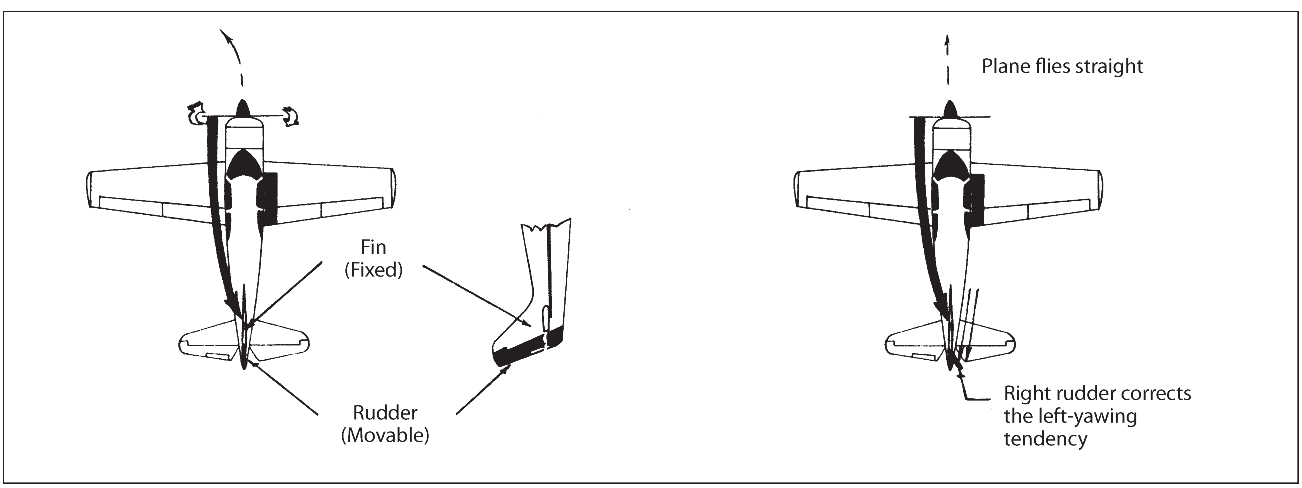


Figure 2-9. The slipstream effect makes the airplane want to yaw to the left.

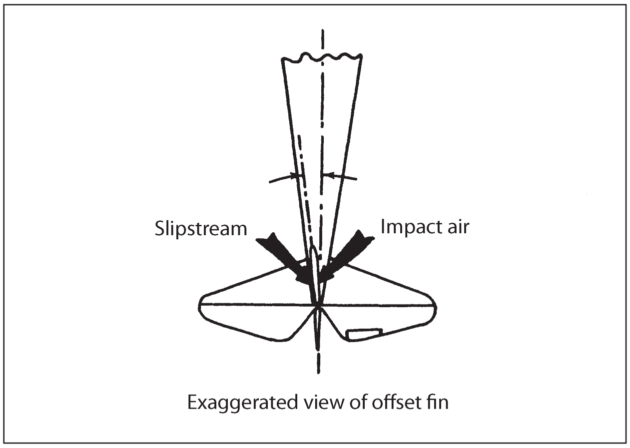


Figure 2-10. The fin of this example airplane is offset to balance the yawing forces at cruise.

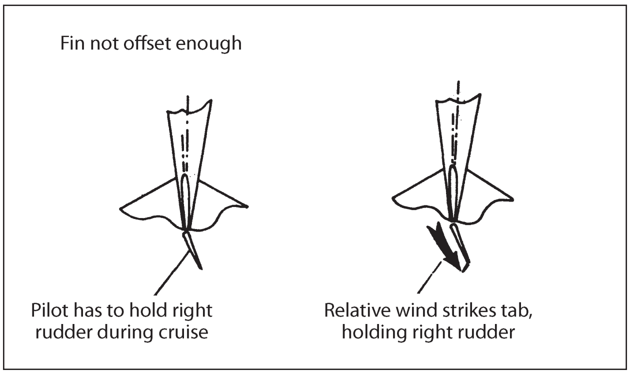


Figure 2-11. The bendable rudder tab corrects for minor yaw problems at cruise. Some airplanes have a rudder tab that is controllable from the cockpit. (*See* Chapter 8.)

An offset fin may be used to counteract this reaction. The fin setting is usually built in for maximum effectiveness at the rated cruising speed of the airplane, since the airplane will be flying most of the time at cruising speed (Figure 2-10).

The balance of forces at this point results in no yawing force at all, and the plane flies straight with no right rudder being held.

Sometimes the fin may not be offset correctly due to tolerances of manufacturing, and a slight left yaw is present at cruising speed, making a constant use of right rudder necessary to hold the airplane straight. To take care of this, a small metal tab is attached to the trailing edge of the rudder and is bent to the left. The relative air pressure against the tab forces the rudder to the right (Figure 2-11).

On many lightplanes this adjustment can be accomplished only on the ground. The tab is bent and the plane is test flown. This is done until the plane has no tendency to yaw in either direction at cruising speed.

Assuming that you have the tab bent correctly and the plane is balanced directionally, what happens if you vary from cruising speed? If the same power setting of 2,400 rpm, for instance, is used, the arrows in Figure 2-12 show a simplified approach to the relative forces at various airspeeds.

In a climb, right rudder is necessary to keep the plane straight. In a dive, left rudder is necessary to keep it straight.

In a glide there is considered to be no yawing effect. Although the engine is at idle and the torque effect is less, the airspeed is lower and the effect of the offset fin is also less.

Some manufacturers use the idea of "canting" the engine slightly so that the thrust line of the propeller (or crankshaft) is pointing slightly to the right. The correction for a left-yawing tendency at cruise is taken care of in this way rather than by offsetting the fin. In such installations, however, right rudder is still necessary in the climb and left rudder in a dive under the conditions shown in Figure 2-12.

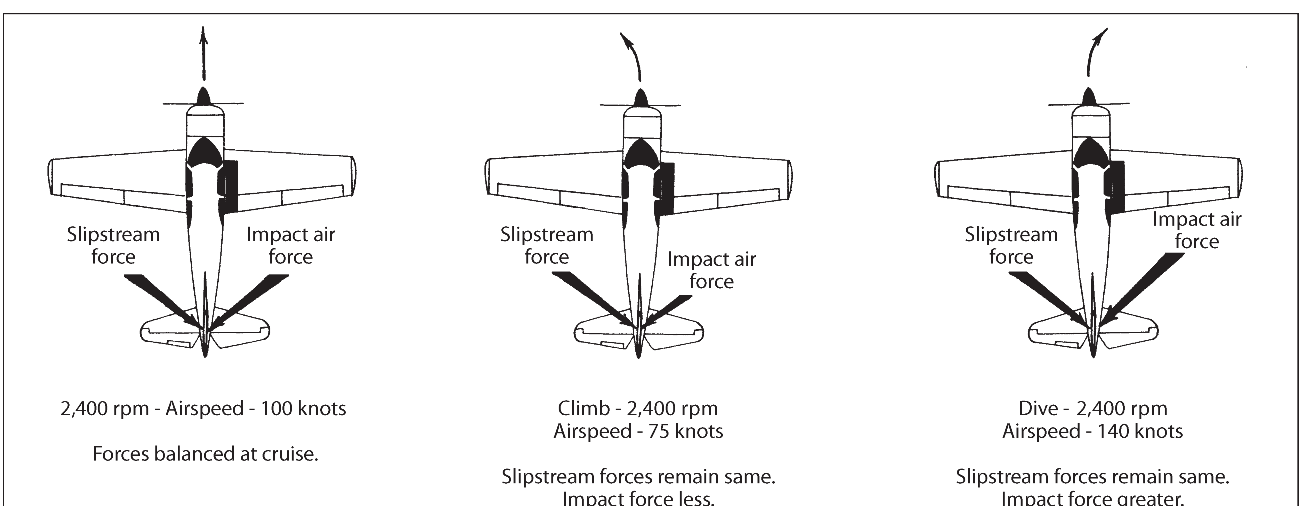


Figure 2-12. A comparison of forces at various airspeeds (constant rpm).

Another less important contributor to the "torque effect" is the tendency of the airplane to rotate in an opposite direction to that of the propeller (for every action there is an opposite and equal reaction). The manufacturer flies each airplane and "rigs" it, making sure that any such rolling tendency is minimized. They may "wash in" the left wing so that it has a greater angle of incidence (which results in a higher angle of attack for a particular nose attitude) than that of the right wing. This is the usual procedure for fabric-covered airplanes, resulting in more lift and more drag on that side. This may also contribute very slightly to the left yaw effect. In some airplanes, a small metal tab on one or both of the ailerons can be bent to deflect the ailerons as necessary, using the same principle described for the rudder tab (the tab makes the control surface move). The controls and their effects will be discussed in Chapter 8, and you may want to review this section again after reading that chapter. Figure 2-13 shows the ailerons and aileron tab.

Two additional factors that under certain conditions can contribute to the torque effect are gyroscopic precession and what is termed "propeller disk asymmetric loading" or "P factor." Gyro precession acts *during* attitude changes of the plane, such as those that occur in moving the nose up or down or yawing it from side to side. Gyro precession will be discussed in Chapters 3 and 13. Asymmetric loading is a condition usually encountered when the plane is being flown at a constant, positive angle of attack, such as in a climb or the tail-down part of the tailwheel airplane takeoff roll (Chapter 13). The downward-moving blade, which is on the right side of the propeller arc as seen from the cockpit, has a higher angle of attack and higher thrust than the upward-moving blade on the left. This results in a left-turning moment.

Actually the problem is not as simple as it might at first appear. To be completely accurate, a vector system including the propeller angles and rotational velocity and the airplane's forward speed must be drawn to get a picture of the exact angle of attack difference for each blade. In other words, if the plane is flying at an angle of attack of 10°, this *does not* mean that the downward-moving blade has an effective angle of attack 10° greater than normal and that the upward-moving blade has an effective angle 10° less than normal, as might be expected.

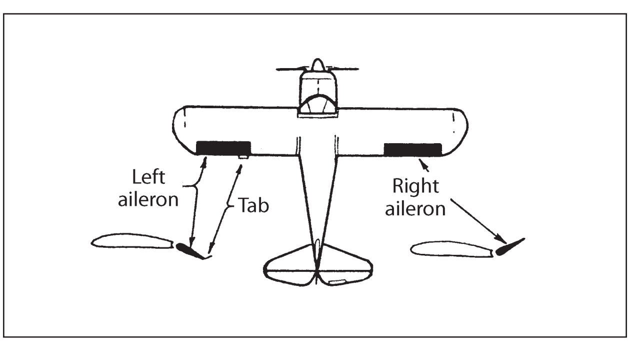


Figure 2-13. Your trainer may have a bendable tab on the aileron(s).

From a pilot's standpoint, you are only interested in what must be done to keep the plane straight. *When speaking of "torque," the instructor is including such things as the rotating slipstream, gyroscopic effects, asymmetric disk loading (P factor), and any other power-induced forces or couples that tend to turn the plane to the left.*

Drag

Anytime a body is moved through a fluid (such as air), drag is produced. Drag acts parallel to and in the same direction as the relative wind. The "total" drag of an airplane is composed of two main types of drag, as shown by Figure 2-14.

Parasite drag (Figure 2-15)—the drag composed of (1) "form drag" (the landing gear and radio antennas, the shape of the wings, fuselage, etc.), (2) skin friction, and (3) airflow interference between components (such as would be found at the junction of the wing and fuselage or fuselage and tail). As the word "parasite" implies, this type of drag is of no use to anybody and is about as welcome as any other parasite. However, parasite drag exists and it's the engineer's problem to make it as small as possible. Parasite drag increases as the square of the airspeed increases. Double the airspeed and parasite drag increases *four* times. Triple the airspeed and parasite drag increases *nine* times.

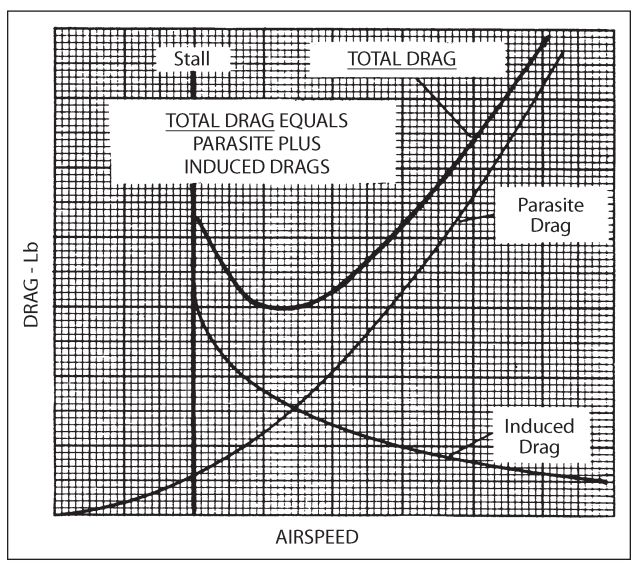


Figure 2-14. The total drag of the airplane is made up of a combination of parasite and induced drag.

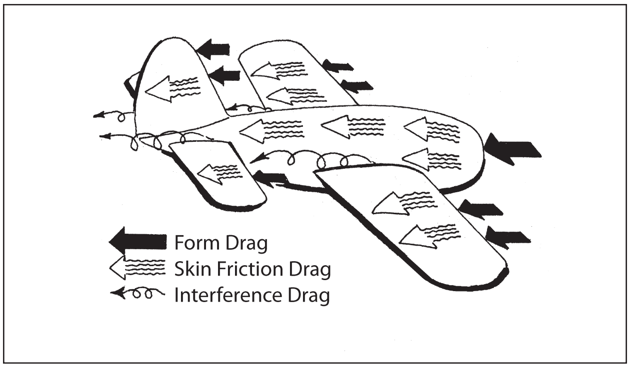


Figure 2-15. Parasite drag.

Induced drag—the drag that results from lift being produced. The relative wind is deflected downward by the wing, giving a rearward component to the lift vector called *induced drag* (the lift vector is tilted rearward—*see* Figure 2-16). The air moves over each wing tip toward the low pressure on the top of the wing and vortices are formed that are proportional in strength to the amount of induced drag present. The strength of these vortices (and induced drag) increases radically at higher angles of attack so that the *slower* the airplane flies, the *much greater* the induced drag *and* vortices will be (Figures 2-14, 2-16, and 2-17).

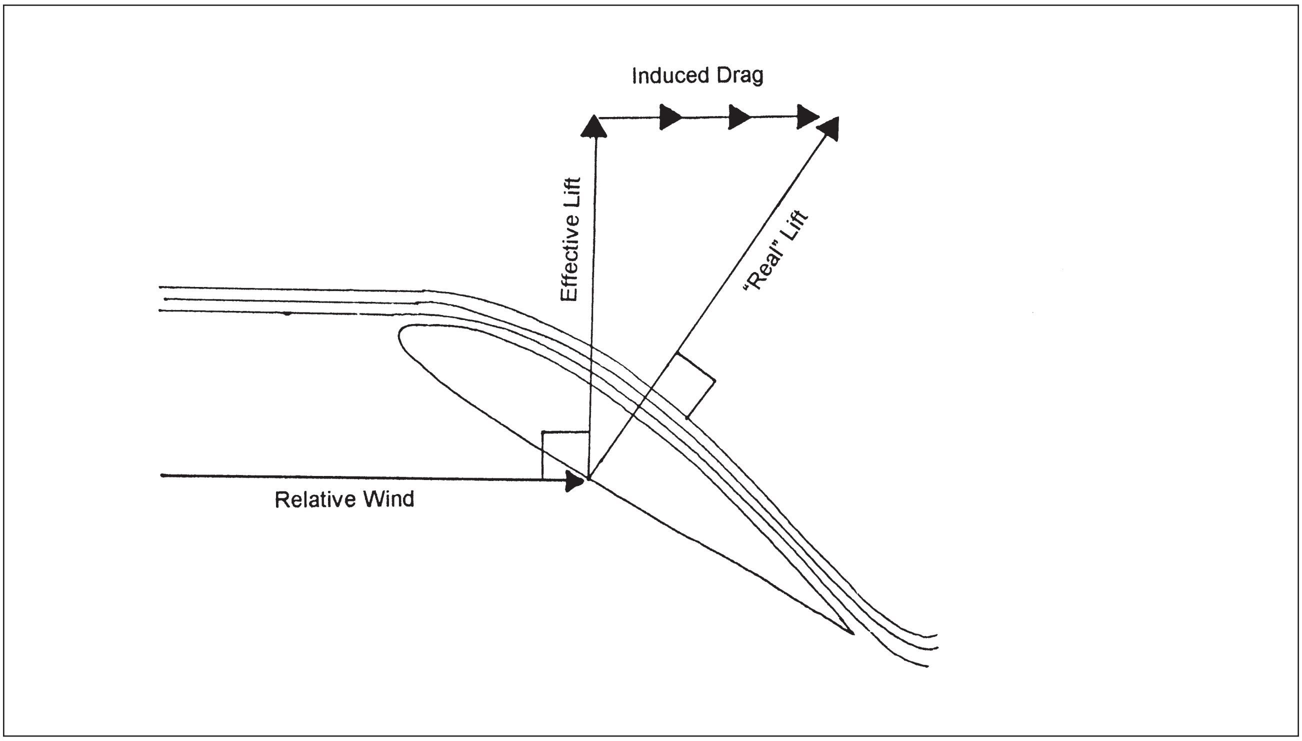


Figure 2-16. Induced drag.

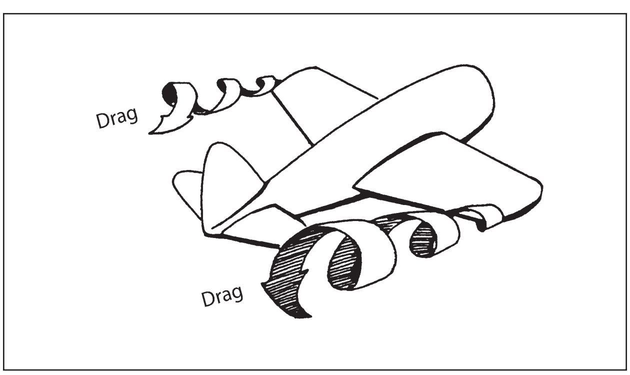


Figure 2-17. Wing tip vortices.

Weight

Gravity is like the common cold, always around and not much that can be done about it. This can be said, however: Gravity always acts "downward" (toward the center of the earth). Lift does not always act opposite to weight, as you will see in Chapter 9.

3

Cockpit — Instruments and Systems

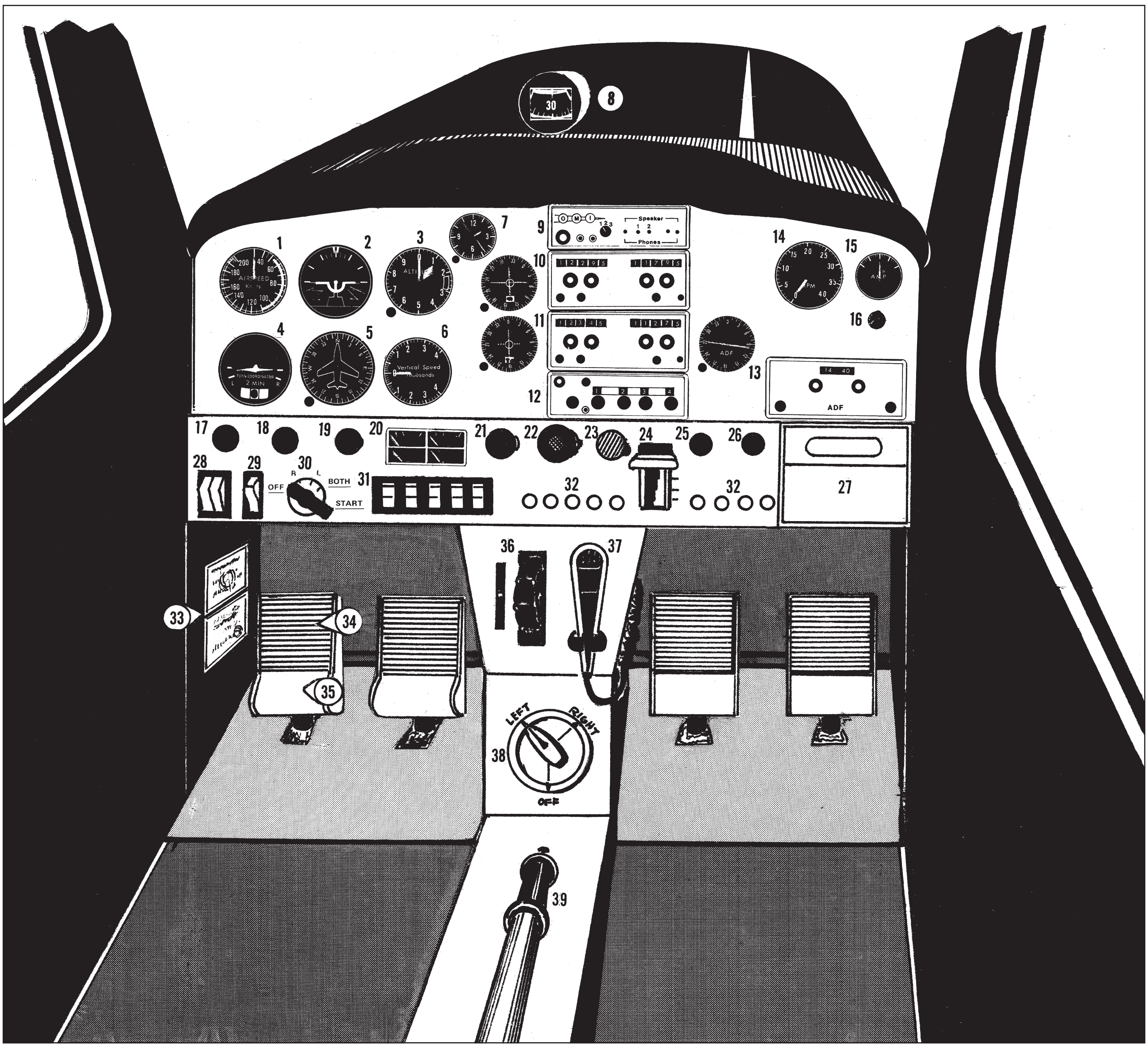


Figure 3-1. The controls, radios, and instruments for a generic aviation trainer. Some trainers have a "glass cockpit," where the flight instruments are combined and shown on screens, with integrated GPS information. This book is aimed at the basics, however.

Figure 3-1 shows controls and instruments for a "composite" airplane. The seats and control wheels have been "removed" for clarity. Chapter references indicate where more information may be found concerning each item. If there is no reference, the item is covered in this chapter. (Glass cockpits are touched on at the end of this chapter.)

1. *Airspeed indicator* (ASI).
2. *Attitude indicator.*
3. *Altimeter.*
4. *Turn coordinator.*
5. *Heading indicator.*
6. *Vertical speed indicator* (VSI).
7. *Clock.*
8. *Magnetic compass.*
9. *Audio Console.* This contains the transmitter selector (the black knob) that, in this installation, allows you to select the number one transmitter (item 10) or the second transmitter (item 11). You can also choose whether you want to listen to a selected set on the cabin speaker or through the earphones (also noted in item 37). *See* Chapter 21.
10. *NAV/COMM* or *COMM/NAV set,* a combination of communications equipment and VHF omnirange (VOR) receiver and indicator (also called a "one-and-a-half" set). The left side of the equipment, or the "one," is the communications *transceiver* (transmitter/receiver); the right side is a navigation *receiver* (the "half"). *See* Chapter 21.
11. The second *NAV/COMM control* and *VOR indicator*.
12. *Transponder/ADS-B* (Chapter 21).
13. Although still installed in some trainers, the automatic direction finder (ADF) shown here has probably been replaced by a GPS unit and display in your airplane. The transmitting non-directional beacons (NDBs) used by the ADF are being decommissioned in the lower 48 states. You'll get familiar with more complex avionics as you progress to higher certificates and ratings.
14. *Tachometer* (indicates engine rpm).
15. *Ammeter.*
16. *Suction gauge,* the instrument that indicates the drop in inches of mercury created by the engine-driven vacuum pump. The vacuum pump provides the suction to operate the attitude indicator, directional gyro, and in some cases, the turn and slip indicator. (In most cases the turn coordinator or turn and slip is electrically driven as a backup.)
17. *Primer* (Chapter 5).
18. *Parking brake.*
19. *Rheostat* to control the brightness of the instrument panel and radio dial lights (Chapter 26).
20. *Engine instrument cluster,* which may include fuel quantity, fuel pressure, oil pressure, and oil temperature gauges. High-wing trainers that depend on gravity for fuel feeding do not have a fuel pressure gauge. Low-wing airplanes have an engine-driven fuel pump (something like that in your car) and must have an electrically driven pump as a standby, so a fuel pressure gauge is required (Chapters 5 and 7).
21. *Carburetor heat* (Chapter 4).
22. *Throttle* (Chapters 2, 5, and 7).
23. *Mixture control* (Chapter 5).
24. *Electric flap control.* You move the handle down to the indentations (notches) to preselect, for instance, 10-degree, 20-degree, or 30-degree of flap deflection (Chapter 13).
25. *Cabin heat control* (Chapter 4).
26. *Cabin air control.* A combination of cabin air and cabin heat may be used to control the temperature and flow rate in the cabin.
27. *Map compartment* (used to hold most everything except maps).
28. *Master switch,* which, as will be discussed later in this chapter, is a "split" switch to control both the alternator and the battery.
29. *Electrically driven fuel pump* (low-wing airplanes) mentioned in item 20. This is turned ON as an aid in starting (for some airplanes) and as a safety standby for takeoff and landings if the engine-driven fuel pump should fail (Chapter 7).
30. *Ignition switch.* The airplane has left (L) and right (R) magnetos to furnish ignition. The airplane is flown with the key in the BOTH position, using both magnetos. To start the airplane, the key is turned past the BOTH position to the spring-loaded START. After starting, the key is released and moves back to BOTH (Chapter 4).
31. *Electrical switches.* These will be for navigation (position) lights, wing tip strobes, and a red rotating beacon on the top of the fin. There will also be a taxi and landing light switch for most airplanes.
32. *Circuit breaker panel* for the items that depend on the electrical system, such as radios and lights. These circuit breakers (fuses are used for various items in some airplanes) are designed to stop any overloading of circuits and are "safety cutoffs" to prevent fire or damage to the system.
33. *Aircraft papers.* The Airworthiness Certificate must be *displayed* (*see* end of chapter).
34. *Toe brake* (left) (Chapter 6).
35. *Rudder pedal* (Chapters 6 and 8).
36. *Elevator* or *stabilator trim wheel and indicator.*
37. *Microphone.* For receiving, the speaker (usually located on the cabin ceiling) is often used; however,

your trainer may have headsets. Many planes have both a speaker and earphones, and the pilot selects whichever method of receiving is preferred. *See* the right side of item 9.

38. *Fuel selector valve.* This example airplane has a tank in each wing and is selected to use fuel from the left wing tank. The OFF selection is very seldom used, but the selector valve should *always* be checked before starting to make sure the fuel selector is on an operating (and the fullest) tank (Chapter 23).
39. *Manual flap control.* The flap handle is operated in "notches," giving various preset flap settings. The button on the end of the handle is used to unlock the control from a previous setting. Your trainer will probably have one of the two types (items 24 and 39) shown here, but not both. Or your trainer may not have flaps (Chapter 13).

Required Instruments

Altimeter

The altimeter is an aneroid barometer with the face calibrated in feet instead of inches of mercury. As the altitude increases, the pressure decreases at the rate of about 1 inch of mercury for each 1,000 feet of altitude gain. The altimeter contains a sealed flexible diaphragm, correct only at sea level standard pressure (29.92 inches of mercury) and sea level standard temperature (59°F or 15°C). Indicating hands are connected to the diaphragm and geared so that a small change in the diaphragm results in the proper altitude indications. The altimeter has three hands. The longest indicates hundreds of feet and the medium-sized hand, thousands of feet. Another pointer indicates tens of thousands of feet, but it is doubtful if you will have a chance to use this one for a while.

A small window at the side of the face allows the altimeter to be set to the latest barometric pressure as corrected to sea level. As you know, the atmospheric pressure is continually changing and the altimeter, being a barometer, is affected by this.

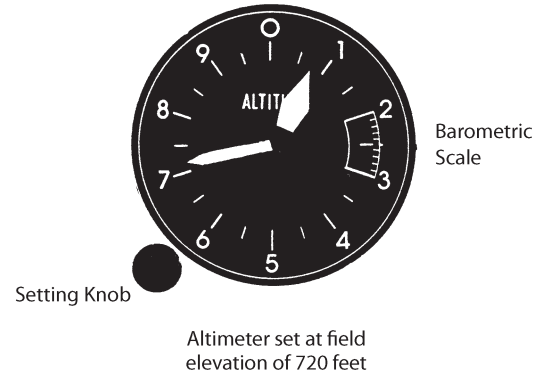


Figure 3-2. Altimeter setting.

Suppose that while you're flying, the pressure drops at the airport (maybe a low-pressure area is moving in). After you land, the altimeter will still be "in the air" because of the lower pressure. The instrument only measures the pressure and has no idea where the ground is unless you correct for pressure changes. The altimeter is usually set at field elevation so that a standard may be set among all planes. In other words, pilots fly their altitude with respect to sea level. The elevations of the airports around the country vary, and if the altimeters were set at zero for each field there would be no altitude standardization at all. The altitude you read when the altimeter has been set to the present corrected station barometric pressure is called "mean sea level" (MSL) or indicated altitude. Remember that this does not tell you how high you are above the terrain at a particular time. As an example, assume your field elevation is 720 feet. Set the altimeter at 720 feet with the setting knob, as shown in Figure 3-2.

If you want to fly at 2,000 feet above the local terrain, your indicated altitude will be 2,720, or 2,720 feet above sea level (Figure 3-3). If you were asked your altitude by a ground station (or another plane) you'd answer, "2,720."

You can contact FSS or listen to the airport's weather broadcast or download the weather to get the latest altimeter setting (more on the last two methods later). This will give the barometric pressure in inches

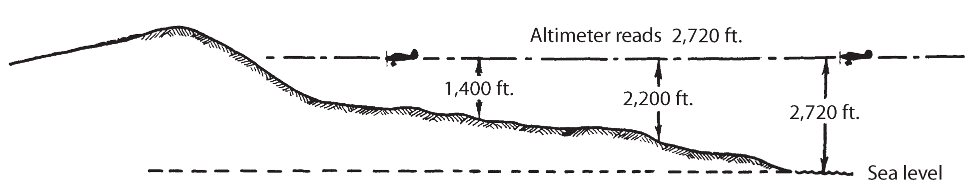
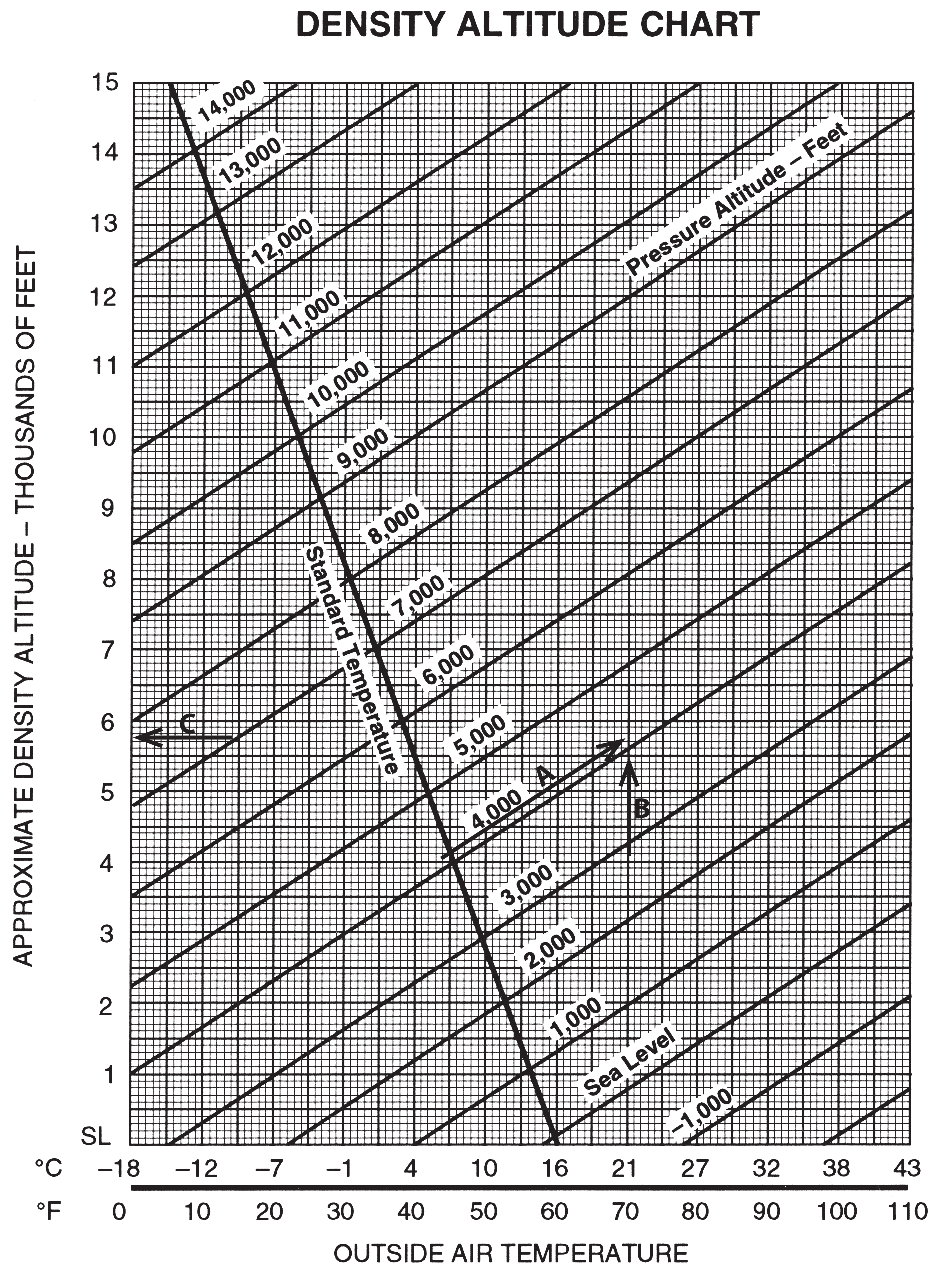


Figure 3-3. *Absolute altitude* is the height above the surface. *True altitude* is the height above mean sea level. *True altitude* is a constant 2,720 feet here.

of mercury, corrected to sea level. You'll set this in the small barometric scale on the altimeter and this will correct for any pressure difference between your home field and the destination. The altimeter should read the destination field's elevation after you land. If not, there's an altimeter error.

Airplanes used for instrument flying must have had their altimeter(s) and static pressure system (*see* Figure 3-5) tested and inspected to meet certain minimums, within the past 24 calendar months by the manufacturer or a certificated repair facility.



Altimeter Setting (" Hg)	Pressure Altitude Conversion Factor
28.0	1,824
28.1	1,727
28.2	1,630
28.3	1,533
28.4	1,436
28.5	1,340
28.6	1,244
28.7	1,148
28.8	1,053
28.9	957
29.0	863
29.1	768
29.2	673
29.3	579
29.4	485
29.5	392
29.6	298
29.7	205
29.8	112
29.9	20
29.92	0
30.0	–73
30.1	–165
30.2	–257
30.3	–348
30.4	–440
30.5	–531
30.6	–622
30.7	–712
30.8	–803
30.9	–893
31.0	–983

Figure 3-4. Finding the density-altitude when altimeter setting and temperature are known. Another example:

Assume an altimeter setting of 29.80 and an outside air temperature of 21°C at an indicated altitude of 4,000 feet. What is the density-altitude as found by this chart?

First, correct the indicated altitude to the pressure altitude by *adding* 112 feet (*see* the conversion factor above for 29.80). The pressure-altitude is 4,112 feet (it's higher than indicated altitude because the pressure is *lower* than the standard of 29.92 inches of mercury).

You move up and to the right on the pressure altitude at 4,112 feet (A) until intersecting the 21°C outside air temperature (B) to get a density-altitude of approximately 5,800 feet — sure, it's hard to read that closely on the graph; a calculator gave an answer of (C) 5,734 feet. Try reading *that* on the graph! (FAA-CT-8080-2E)

When you fly from a high- to a low-pressure area, the altimeter reads too high: H to L = H. When you fly from a low- to a high-pressure area, the altimeter reads too low: L to H = L. In other words, when you fly from a high-pressure region into one of lower pressure, the altimeter "thinks" the plane has climbed and registers accordingly, when actually your altitude above sea level may not have changed at all. Since you will be flying in reference to the altimeter, this means that you will fly the plane down to what appears to be the correct altitude and will be low. If the outside temperature at a particular altitude is lower than standard, the altimeter will read higher than the airplane's actual altitude if not corrected. HALT (**H**igh **A**ltimeter because of **L**ow **T**emperature). Higher than standard temperature means an altimeter that reads low. Up ahead, Figure 19-13 shows how to correct for a nonstandard temperature.

As an example of flying from a high- to a low-pressure area, suppose you take off from an airport where the altimeter setting is 30.10 inches (corrected to sea level) and fly to one with an actual altimeter setting of 29.85 (corrected to sea level). If you forget to reset the altimeter before you land, the altimeter would read approximately 250 feet higher than the actual field elevation. In other words, sitting parked at the new airport's field elevation of 1,000 feet, the altimeter would read 1,250 feet, and "thinks" you're still 250 feet above the airport.

At lower altitudes, for approximately each 1.0 inch of mercury change, the altimeter (if not reset for the new pressure) would be 1,000 feet in error. The actual atmospheric pressure change was from 30.10 down to 29.85, a value of 0.25 inches, or the altimeter "climbed" 250 feet during your flight. The barometric scale in the setting window follows the needle movement as you use the setting knob, and vice versa. If you use the knob to *decrease* the 1,250-foot reading to the field elevation of 1,000 feet, the window will indicate 29.85. Or, if when approaching the airport, you were given the correct altimeter setting by radio, you would *decrease* the window setting to 29.85 and thereby *decrease* the altimeter indication by 250 feet and be right on the field elevation when you land.

Pressure-altitude is shown on the altimeter when the pressure in the setting window is set at 29.92, meaning that this is your altitude as far as a standard-pressure day is concerned. Unless the altimeter setting on the ground is exactly 29.92 and the pressure drop per thousand feet is standard, the pressure altitude and indicated altitude will be different. Pressure altitude computed with temperature gives the density-altitude, or the standard altitude where the density of the air at your altitude is normally found.

Density-altitude is used for computing aircraft performance. In your flying, you will use indicated altitude or the altitude as given by the actual barometric pressure corrected to sea level. Figure 3-4 is a chart for computing density-altitude if pressure altitude and temperature are known.

As an example, the altimeter setting is 29.92, (which is the standard), the pressure altitude is 2,000 feet, and the outside air temperature is 70°F (21°C). From the temperature, move up until the 2,000-foot pressure altitude line is intersected. Running horizontally from that point, a density-altitude of about 3,200 feet is found. In other words, the warmer than standard temperature has lowered the air density so that the airplane would operate as if it was at 3,200 feet, when it's actually 2,000 feet above sea level.

Note that there is a pressure altitude conversion factor in Figure 3-4 to be used if the altimeter setting is not the standard 29.92. You would calculate the density-altitude by correcting the pressure altitude with the conversion factor and then finding the density-altitude as before.

For instance, the altimeter setting is 29.5 (29.50), the field elevation is 2,900 feet, and the outside temperature is 80°F (27°C). First, you'd correct the pressure altitude by adding 392 feet (the altitude correction at 29.5 inches of mercury) to get 3,292 feet of pressure altitude (call it 3,300). Draw a line up the vertical line from 80°F to intersect this pressure altitude value and then move horizontally from this point to read a density-altitude of about *5,300 feet*. Although the airplane is sitting at an airport at 2,900 feet above sea level, because of the lower atmospheric pressure and higher temperature (making the air "thin") it will only perform as if it's at 5,300 feet above sea level. *The runway might not be long enough for a safe takeoff under these conditions.* The computations seem to be a little complicated right now, but come back and look at Figure 3-4 again after you've read Chapter 17.

Airspeed Indicator

The airspeed system is composed of the pitot and static tubes and the airspeed indicator instrument (Figure 3-5). The pitot-static system measures the dynamic pressure of the air. As the airplane moves through the air, the relative wind exerts a "ram" pressure in the pitot tube. This pressure expands a diaphragm that is geared to an indicating hand. This pressure is read as airspeed (in miles per hour, or knots) rather than pressure. In short, the pitot-static system measures the pressure of the relative wind approaching the wings (and the

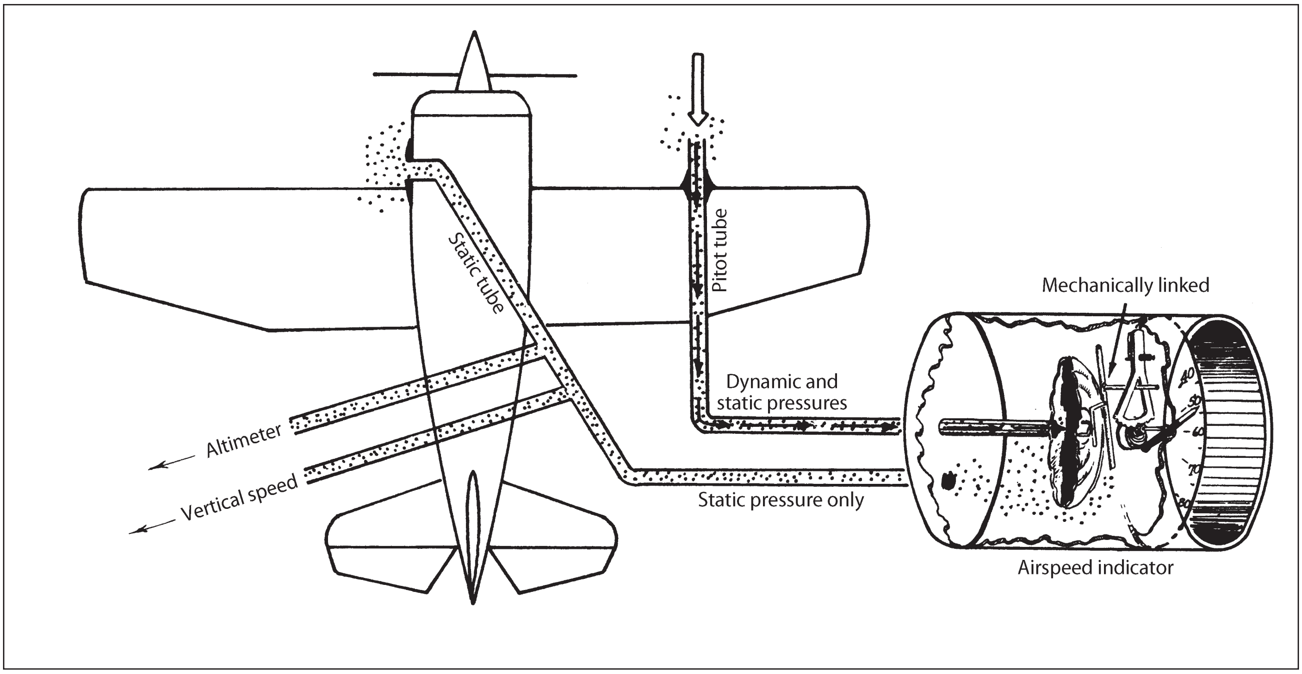


Figure 3-5. Typical general aviation trainer airspeed indicator and pitot-static system. The airspeed, altimeter, and vertical speed indicators rely on the static tube for the ambient static pressure. In addition, the airspeed needs the pitot tube for the entrance of dynamic pressure into the diaphragm. As shown, the pitot tube also contains static pressure, which is "cancelled" by the static pressure in the static tube and inside the case.

entire plane, for that matter). A pitot tube alone would not tell the pilot how much of this pressure was the dynamic pressure giving the wings their lift. The static tube equalizes the static pressure within and without the system, leaving only the dynamic pressure or airspeed being measured. You will check the pitot tube and static vent openings during the preflight inspection, as will be covered in Chapter 4.

Let's discuss *airspeed* and *groundspeed* while we're on the subject. Once a plane is airborne, it is a part of the air. The airplane moves through the air, but the air itself may move over the ground. The plane's performance is not affected by the fact that the entire mass is moving. It is only affected by its relative motion to the mass.

At a certain power setting for a certain attitude, a plane will move through the air at a certain rate, this rate being measured by the airspeed indicator. Figure 3-6 shows the idea, using "true" airspeed or its real speed in relation to the air moving past the airplane.

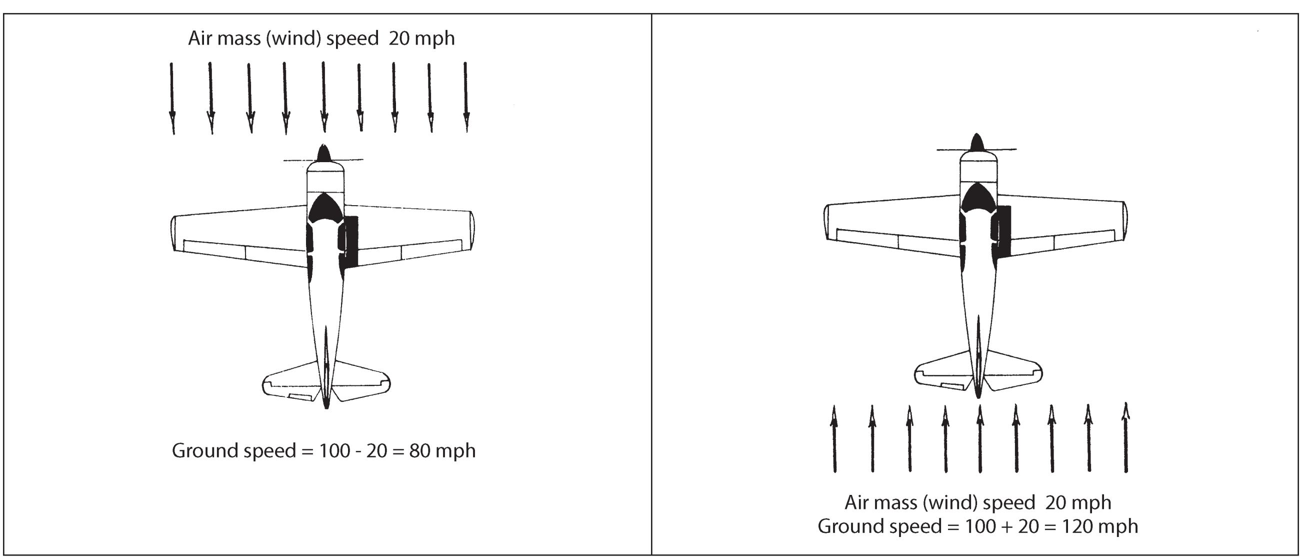


Figure 3-6. The airplane's true airspeed is 100 mph; its groundspeeds are 80 and 120 mph, as shown.

Groundspeed is like walking on an escalator. If you're walking against the escalator at its exact speed, you make no progress. By walking with the escalator, your speed is *added* to its speed. Chapter 10 goes into more detail on this.

Lightplane airspeed indicators are calibrated for standard sea level operation (59°F and 29.92 inches of mercury). As you go to higher altitudes, the air will be less dense and therefore there will be less drag. The plane will move faster, but because of the lesser density, airspeed will register less than your actual speed. This error can be corrected roughly by the rule of thumb: "Add 2 percent per thousand feet." This means that if your "calibrated" airspeed is 100 mph at 5,000 feet, your "true" airspeed is 5 × 2 = an additional 10 percent = (.10)(100) = 10 mph + 100 mph = 110 mph. This works generally up to about 10,000 feet, but for closer tolerances and altitudes above this, a computer should be used.

The computer takes into consideration any deviation of temperature and pressure from the "normal lapse rate." *The standard temperature at sea level is 59°F (15°C). The normal lapse rate, or temperature drop, is 3½°F (2°C) per thousand feet.* The "2 percent per thousand feet" rule of thumb uses this fact and does not take into consideration any change from the normal lapse rate or from standard conditions.

The calibrated airspeed mentioned above is the corrected indicated airspeed, so in order to find the true airspeed the following steps would apply:

1. *Indicated airspeed (IAS) + Instrument and position error = calibrated airspeed (CAS).*
2. *Calibrated airspeed plus pressure altitude and temperature correction (2 percent per thousand feet, or use a computer) gives the true airspeed (TAS).* (Most lightplanes have IAS correction information, but for others, assume IAS to equal CAS.)

Looking back at the lift equation in Chapter 2 you'll see in it the expression $(\rho \div 2) \times V^2$. This is the dynamic pressure that contributes to the wing's lift and is measured by the airspeed indicator, as discussed earlier. For instance, at an indicated 100 mph the dynamic pressure is about 25.5 psf. Your airspeed indicator is made so that when dynamic pressure of that value enters the pitot tube, the hand will point to 100 mph. At sea level air density, your motion relative to the air will actually be 100 mph when the airspeed indicates this amount (assuming that the instrument is completely accurate).

As you know, the air density decreases with altitude. When you are at 5,000 feet and are indicating 100 mph (25.5 psf), the airspeed indicator doesn't reason that the plane is actually moving faster in relation to the air and making up for the lower density in the dynamic pressure equation. All the indicator knows is that 100 mph worth of dynamic pressure is being routed into it and leaves it up to you to find the "true" airspeed, or the plane's actual speed in relation to the air mass at the higher altitude.

If your plane indicates 50 mph at the stall at sea level, it will indicate 50 mph at the stall at 5,000 or 10,000 feet (assuming the same airplane weight and angle of bank; in Chapter 9 you'll see why such a condition is made). This is because a certain minimum dynamic pressure is required to support the airplane, and for your plane it happens to be an indicated 50 mph (or about 6.4 psf).

Another airspeed you may hear about is equivalent airspeed (EAS). At higher airspeeds and altitudes, compressibility errors are induced into the system. Looking back at Figure 3-5, you see that there is static pressure in the *instrument case*, which (theoretically, anyway) cancels out the static pressure in the *diaphragm* (let in through the pitot tube). At high speeds where compressibility is a factor, the effect is that of "packing" and raising the pressure of the *static* air in the pitot tube and diaphragm. The static air in the *case* doesn't get this effect, so that indicated (and calibrated) airspeeds are shown as *higher* than the actual value. A correction is made to obtain the "correct" CAS; this is called the *equivalent* airspeed. EAS would then be used to find the TAS. For high-speed airplanes the correction would be:

1. IAS plus (or minus) instrument and position error = CAS.
2. CAS minus compressibility error = EAS.
3. EAS corrected for pressure altitude and temperature = TAS.

You won't have to cope with compressibility errors for the airplane you are training in, but you should be aware that such factors do exist.

The calibrated airspeed is the "real" airspeed affecting the flying of the airplane and is the dynamic pressure $[(\rho/2)V^2]$ in pounds per square foot (psf). If you want to find the dynamic pressure working on the airplane at, say, 100 knots (more about knots shortly), you use the equation V^2 knots/295. At 100 knots, the result is 33.9 psf (call it 34 psf).

You'll note that examples of true airspeed in this section used statute miles per hour. While flying, you'll use the nautical mile (6,080 feet) and knots (1 knot equals 1 nautical mile per hour). Also, 1 nautical mile equals 1.152 statute miles. This book will follow the data as produced in the *Pilot's Operating Handbooks* and use knots (K) for speed and nautical miles (NM) for distance, with a few exceptions to be noted in later chapters. While this will seem strange at first, you'll soon get accustomed to thinking in these terms in flying.

Tachometer

The lightplane tachometer is similar in many ways to a car speedometer. One end of a flexible cable is attached to the engine and the other is connected to the instrument. The rate of turning of the cable, through mechanical or magnetic means, is transmitted as revolutions per minute (rpm) on the instrument face. The average lightplane propeller is connected directly to the engine crankshaft so that the tachometer registers both the engine and propeller rpm. The propeller is usually geared down in larger planes, and in that case the ratio of engine speed to propeller speed can be found in the *Airplane Flight Manual*. At any rate, you always use the engine rpm for setting power because this is what is indicated on the tachometer in the direct drive or geared engine.

Most tachometers have a method of recording flight hours, based on a particular rpm setting (say, 2,300 rpm). This means that the engine is not "building up time" as fast when it's at idle or at lower power settings. The time indicated on the recording tachometer is used as a basis for required inspections and overhauls, and the reading is noted in the logbooks whenever such work is done on the airplane and/or engine.

Oil Pressure Gauge

Every airplane is equipped with an oil pressure gauge (Figure 3-7), and to the majority of pilots it is the most important engine instrument (the fuel gauge runs a close second). Some oil pressure gauges have a curved Bourdon tube in the instrument. Oil pressure tends to straighten the tube, and through mechanical linkage a hand registers the pressure in pounds per square inch. The move now is toward using electrical transmitters and indicators, particularly for more complex engine installations.

Oil pressure should reach the normal operating value within 30 seconds after the engine starts in temperate conditions. The instrument should be checked about every 5 minutes in flight, since it is one of the first indicators of oil starvation, which means engine failure and a forced landing. If the oil pressure starts dropping, land at an airport as soon as safely possible.

There have been many cases of the instrument itself giving bum information. After you notice the falling (or low) oil pressure, keep an eye on the oil temperature gauge for a rising temperature as you turn toward an airport or good landing area. Pilots have depended solely on the oil pressure gauge and landed in bad places when the engine was getting plenty of oil (and the oil temperature stayed normal).

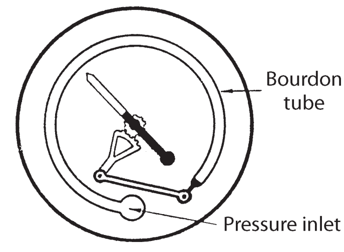


Figure 3-7. Oil pressure gauge.

Oil Temperature Gauge

The vapor-type temperature gauge is used for older lightplanes. The indicating head or instrument contains a Bourdon tube and is connected by a fine tube to a bulb that contains a volatile liquid. Vapor expansion exerts pressure, which is read as temperature on the instrument. Most trainers do not have a cylinder head temperature gauge, so the oil temperature gauge is the only means of telling if the engine is running hot. Most airplanes now use the principle of electrical resistance change for measuring oil temperature. Figure 3-8 shows general aviation oil temperature gauges.

Section 2 of the *Pilot's Operating Handbook* for your airplane will contain the limits of operation and markings for the engine instruments (*see* Figure 3-30).

Compass

The airplane compass is a magnet with an attached face or "card" that enables you to read directions from 0° to 360°.

The magnet aligns itself with the Magnetic North Pole, and the plane turns around it.

Every 30°, the compass has the number of that heading minus the 0. For instance, 60° is 6 and 240° is 24 on the compass card. It's broken down further into 10° and 5° increments. The compass card appears to be backward in the diagram, but as the plane actually turns around the compass, the correct reading will be given.

In a shallow turn, the compass is reasonably accurate on headings of East and West but leads ahead of the turn as the plane's heading approaches South and lags behind as it approaches North. If you are on a heading of *North* and make a turn in either direction, the compass will initially roll to a heading *opposite* to the bank. On a heading of *South* when the turn is started, the compass will initially roll to a heading indication *exceeding* that actually turned (**N**orth–**O**pposite, **S**outh–**E**xceeds, or NOSE). The amount of lead or lag depends on the amount of bank and the latitude at which you are flying. Knowing the amount of lead or lag in the compass you are using will be helpful in rolling out on a heading.

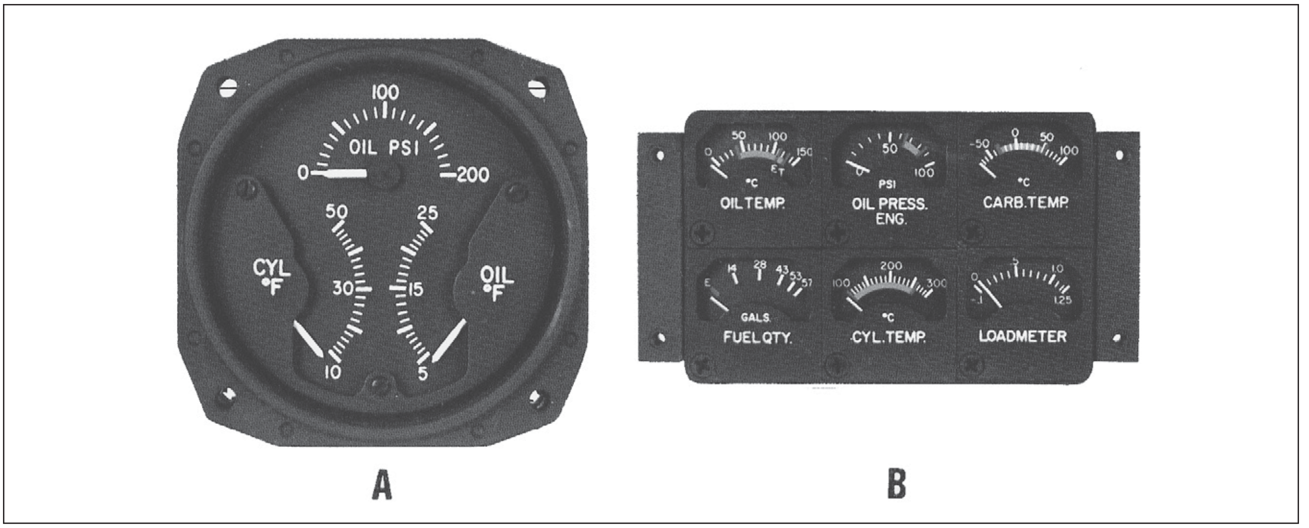


Figure 3-8. (A) Engine instrument cluster with cylinder head and oil pressure and temperature gauges. (B) Another engine instrument cluster arrangement. (Courtesy of Castleberry Instruments and Avionics, Inc.)

Figure 3-9 is a simplified drawing of the magnetic compass. The magnets tend to point parallel to the earth's lines of magnetic force. As the compass is brought nearer to the Magnetic North Pole, the magnets will have a tendency to point toward the earth's surface.

If directly over the Magnetic North Pole, the compass would theoretically point straight down, causing a great deal of confusion to all concerned. The magnetic compass is of little use close to the pole, so other methods of navigation are used in this area.

The suspension of the compass card causes certain problems. For instance, if you are flying on a generally easterly heading and accelerate, the compass will turn toward a northerly heading even though the plane has not turned. This occurs on a westerly heading as well.

If on these headings the plane decelerates, a southerly indication is given under these conditions, as can be seen by referring to Figure 3-9. The following can be noted:

Acceleration—The compass indicates a more northerly heading.

Deceleration—The compass indicates a more southerly heading.

One way of remembering what happens is ANDS (**A**cceleration–**N**orth, **D**eceleration–**S**outh).

Acceleration/deceleration errors are not considered a factor in North and South headings.

When the plane is climbed, dived, or banked (particularly a bank of more than 15°–20°), inaccuracies result. Notice in a climb or glide (on an east or west heading) that the compass inches off its original indication because of the airplane's attitude (assuming that you have kept the nose from wandering). The compass card and magnets have a one-point suspension so that the assembly acts as a pendulum and also will tilt in reaction to various forces and attitudes of flight (acceleration, banks, nose attitudes, etc.). This tilting action is also a major contributing factor to the reactions of the compass. The "floating" compass as described here is used for reference rather than precision flying (Figure 3-10). In turbulence the compass swings so badly that it's very hard to fly a course by it. It's a good instrument for getting on course or keeping a general heading between checkpoints on cross-country, but never blindly rely on it. There will be more about this instrument in later chapters.

Figure 3-11 is a newer type of magnetic compass with a vertical card. The small airplane is fixed; the card turns in a more easily readable way and is like the new faces on the heading indicator in Figure 3-22. Chapter 15 goes into more detail on use of the magnetic compass.

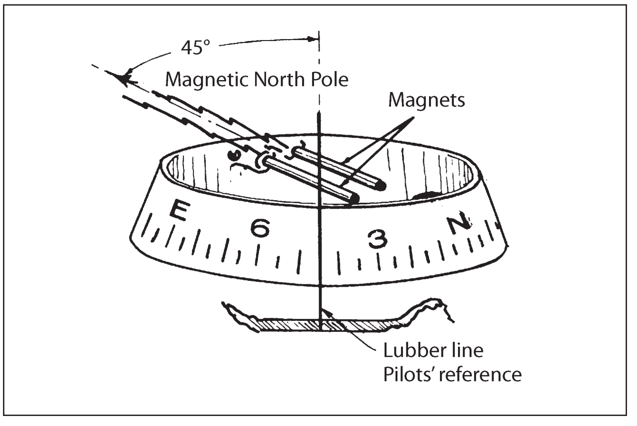


Figure 3-9. Magnetic compass.

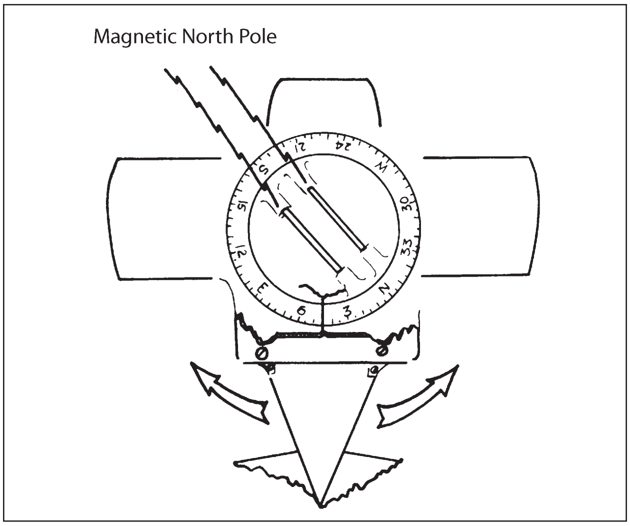


Figure 3-10. The lubber line and instrument case are fastened to the aircraft, which turns around the free-floating compass card and magnets.

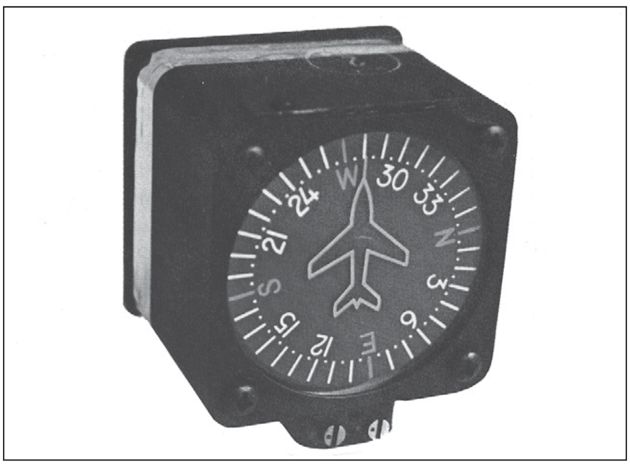


Figure 3-11. Vertical card magnetic compass. (Courtesy of Hamilton Instruments, Inc.)

Additional Instruments

The instruments discussed in the earlier part of this chapter are all that are required for daytime VFR flight, but the instruments discussed below will also be used in your training. Federal Aviation Regulations require that emergency recovery from a loss of visual references (such as accidentally flying into clouds or fog) be demonstrated on the private flight test. There have been a large number of fatal accidents caused by pilots overestimating their abilities and flying into marginal weather. It can be easily demonstrated that "flying by the seat of your pants" when you have lost visual references is a one-way proposition—*down*.

The instruments discussed earlier are used for your day-to-day flying under the VFR (visual) type of flying; for instrument flying (and your instruction in emergency flying using the instruments) more equipment is needed. The FAA requires that on the practical (flight) test the airplane be equipped with "appropriate flight instruments" for checking the pilot's ability to control the airplane by use of the instruments. It's very likely that your trainer will be equipped with all of the instruments covered in this chapter, but techniques are given in Chapter 15 for using only the turn coordinator or turn and slip (plus airspeed and altimeter) to maintain control of the airplane under simulated or actual instrument conditions.

Gyro Instruments in General

Gyro instruments work because of the gyroscopic properties of "rigidity in space" and "precession."

If you owned a toy gyroscope or top in your younger days, the property of "rigidity in space" is well known to you. While the top was spinning, it could not be pushed over but would move parallel to its plane of rotation (on the floor) in answer to such a nudge. The gyroscope resists any effort to tilt its axis (or its plane of rotation) (Figure 3-12). This property is used in the attitude indicator and heading indicator.

The property of "precession" is used in the turn and slip indicator. If a force is exerted against the side of a rotating gyro, the gyro reacts as if the force was exerted at a point 90° around the wheel (in the direction of rotation) from the actual place of application (Figure 3-13).

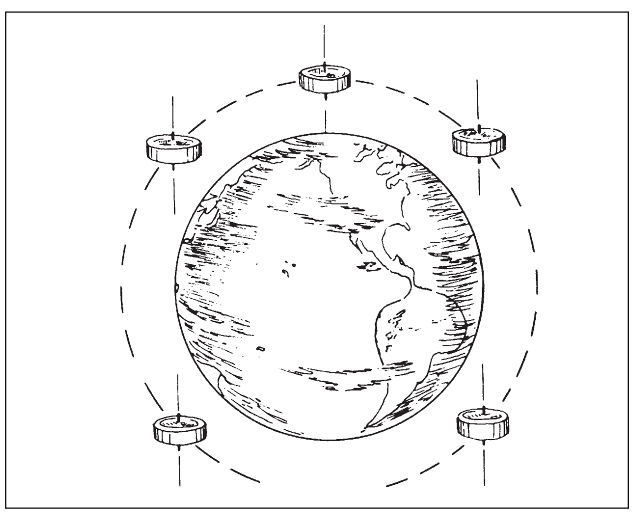


Figure 3-12. The gyro maintains rigidity in space.

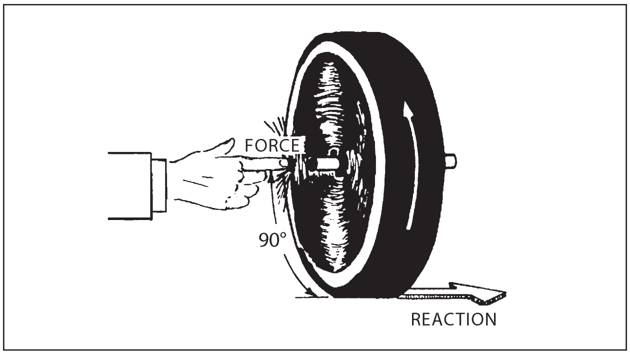


Figure 3-13. Precession

Turn and Slip Indicator (Needle and Ball)

The turn and slip indicator is actually two instruments. The slip indicator is merely a liquid-filled, curved glass tube containing an agate or steel ball. The liquid acts as a shock dampener. In a balanced turn the ball will remain in the center, since centrifugal force offsets the pull of gravity (Figure 3-14).

In a slip there is not enough rate of turn for the amount of bank. The centrifugal force will be weak, and this imbalance will be shown by the ball's falling down toward the inside of the turn (Figure 3-15). (You experience centrifugal force any time you turn a car—particularly in an abrupt turn at high speed as you tend to move to the outside of the turn.)

The skid is a condition in which there is too high a rate of turn for the amount of bank. The centrifugal force is too strong, and this is indicated by the ball's sliding toward the outside of the turn (Figure 3-16).

The slip and skid will be discussed further in "The Turn," in Chapter 9.

The turn part of the turn and slip indicator, or "needle" as it is sometimes called, uses precession to indicate the direction and approximate rate of turn of the airplane.

Figure 3-17 shows the reaction of the turn and slip indicator to a right turn. Naturally, the case is rigidly attached to the instrument panel and turns as the airplane turns (1). The gyro wheel (2) reacts by trying to rotate in the direction shown by (3), moving the needle in proportion to the rate of turn (which controls the amount of precession). As soon as the turn stops, the precession is no longer in effect and the spring (4) returns the needle to the center. The spring resists the precession and acts as a dampener, so the nose must actually be moving for the needle to move. The ball may be off to one side even though the needle is centered. For instance, in a side or forward slip (to be covered later) the airplane may be in a bank with the pilot holding opposite rudder. The ball will be in a more extreme position than that shown in Figure 3-15.

Some turn and slip indicators are calibrated so that a "standard-rate turn" of 3° per second will be indicated by the needle's being off center by one needle width (Figure 3-17). This means that, by setting up a standard-rate turn, it is possible to roll out on a predetermined heading by the use of a watch or clock. It requires 120 seconds (2 minutes) to complete a 360° turn. There are types of turn and slip indicators calibrated so that a double-needle-width indication indicates a standard-rate turn. These have a "doghouse" to

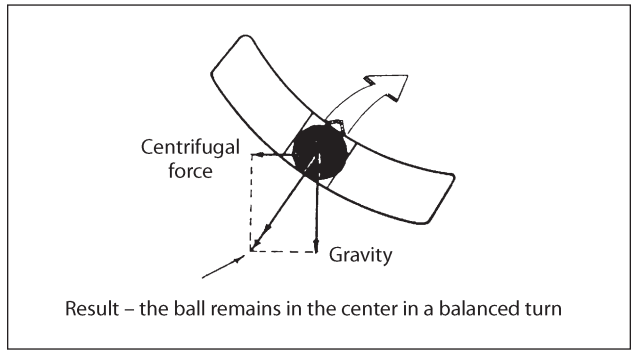


Figure 3-14. A balanced right turn.

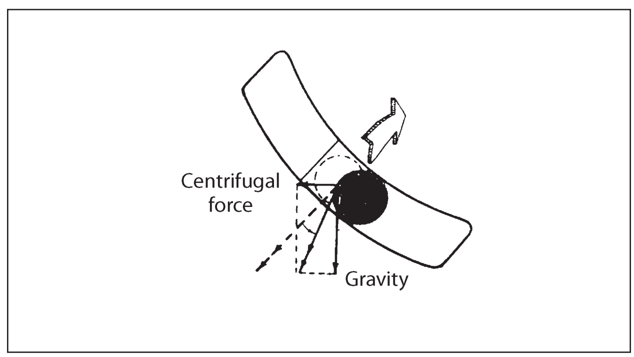


Figure 3-15. A slipping turn.

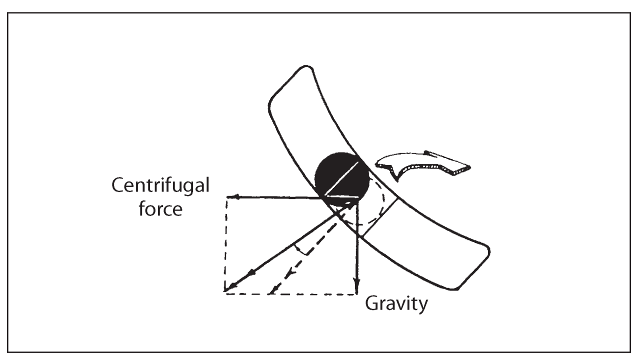


Figure 3-16. A skidding right turn.

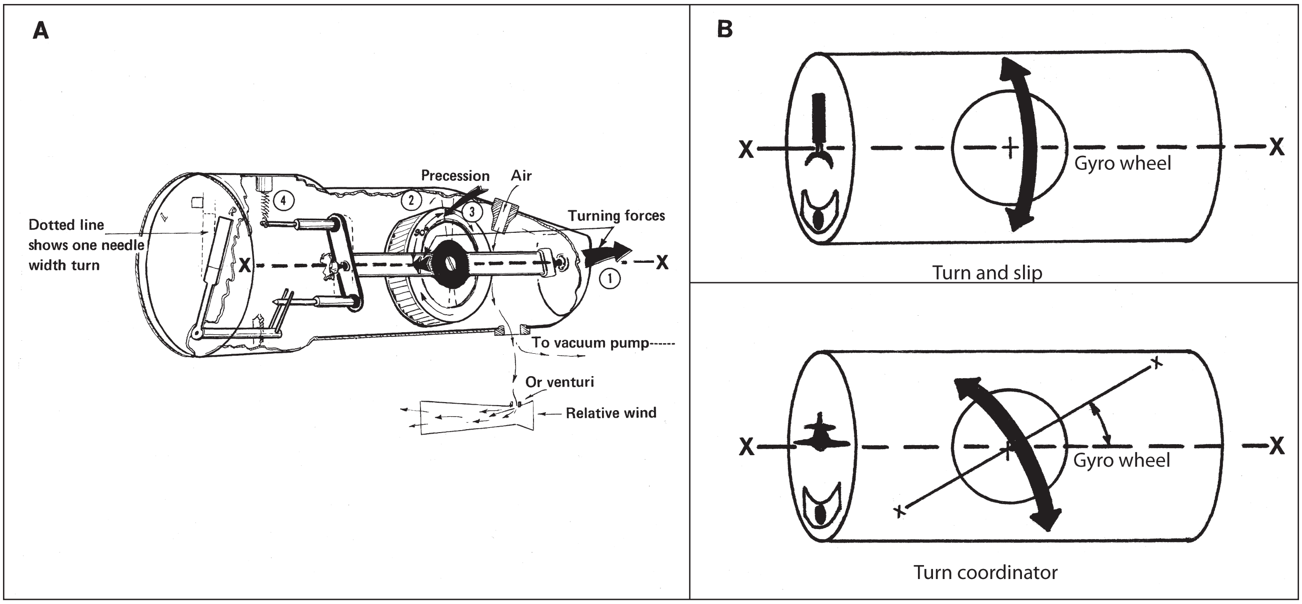


Figure 3-17. (A) Turn and slip indicator (vacuum-driven). Newer instruments are electrically driven. (B) The gyro wheel in the turn and slip is attached in the instrument so that when it reacts to yaw, it can only tilt around the long axis of the instrument (X-X). It is limited in its tilt action by stops. The gyro wheel in the turn coordinator moves (in reaction to precession) around an axis 30° from the long axis of the instrument and so reacts to both roll and yaw inputs. Since precession acts while a force is being *applied*, the turn coordinator only reacts to yaw (rate of turn) once the bank is established.

indicate a standard-rate turn (Figure 3-18 left). If your heading is 070° and you want to roll out on a heading of 240°, first decide which way you should turn (to the right in this case). The amount to be turned is 240 – 70 = 170°. The number of seconds required at standard rate is 170 ÷ 3 = 57. If you set up a standard-rate turn, hold it for 57 seconds, and roll out until the needle and ball are centered, the heading should be very close to 240°. You will have a chance to practice these timed turns "under the hood" (by instruments alone) during your training.

One of the most valuable maneuvers in coping with bad weather is the 180° turn, or "getting the hell out of there." It is always best to do the turn *before* you lose visual contact, but if visual references are lost inadvertently, the 180° turn may be done by reference to the instruments.

The advantage of the turn and slip over other gyro instruments is that the gyro does not "tumble" or become erratic as certain bank or pitch limits are exceeded (*see* "Attitude Indicator").

A disadvantage of the turn and slip is that it is a rate instrument, and a certain amount of training is required before the student is able to quickly transfer the indications of the instrument into a visual picture of the airplane's attitudes and actions.

The gyro of the turn and slip and other gyro instruments may be driven electrically or by air, using an engine-driven vacuum pump or an outside-mounted venturi. (Some airplanes use an engine-driven *pressure* pump.) The venturi is generally used on older lightplanes because of its simplicity; it is nothing more than a venturi tube causing a drop in pressure and drawing air through the instrument past the vanes on the gyro wheel as the plane moves through the air (Figure 3-17).

Turn Coordinator

The turn coordinator also uses precession and is similar to the turn and slip in that a standard rate may be set up but, unlike that instrument, it is designed to respond to roll as well.

Note that the gyro wheel in the turn and slip (Figure 3-17) is vertical and lined up with the axis of the instrument case when yaw forces aren't acting on it. In the turn coordinator the gyro wheel is set at approximately 30° from the instrument's long axis, allowing it to precess in response to both yaw and roll forces (Figure 3-17). After the roll-in (or roll-out) is complete, the instrument indicates the rate of turn. Figure 3-18 compares the indications of the two instruments in a balanced standard-rate turn (3 per second) to the left. Note that the turn coordinator also makes use of a slip indicator (ball).

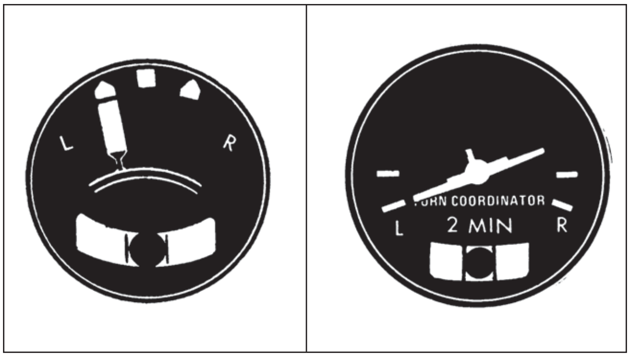


Figure 3-18. A comparison of a standard-rate turn as indicated by the turn and slip and the turn coordinator. The "2 MIN" indicates that if the wing of the miniature airplane is placed on the reference mark, it will take 2 minutes to complete a 360° turn (3° per second).

Attitude Indicator

The attitude indicator (Figure 3-19) or gyro horizon (older name — artificial horizon) depends on the "rigidity in space" idea and is a true attitude instrument. The gyro plane of rotation is horizontal and remains in this position, with the aircraft (and instrument case) being moved about it. Attached to the gyro is a face with a white horizon line and other reference lines on it. When the instrument is operating correctly, this line will always represent the actual horizon. A miniature airplane, attached to the case, moves with respect to this artificial horizon precisely as the real airplane moves with respect to the real horizon. This instrument is particularly easy for students to use because they are able to "fly" the small airplane as they would the large airplane itself.

There are limits of operation on the less expensive attitude indicators and these are, in most cases, 70° of pitch (nose up or down) and 100° of bank. The gyro will "tumble" above these limit stops and will give false information as the gyro is forced from its rotational plane. The instrument will also give false information during the several minutes required for it to return to the normal position after resuming straight and level flight.

"Caging" is done by a knob located on the instrument front and is useful in locking the instrument before doing aerobatics, which include the spin demonstration discussed later. Because it is possible to damage the instrument through repeated tumbling, this caging is a must before you do deliberate aerobatics. Most of the later attitude indicators do not have a caging knob. Figure 3-20 compares two types of attitude indicators (older type is on the left).

The more expensive attitude indicators have no limits of pitch or bank, and aerobatics such as rolls or loops can be done by reference to the instrument. These are used in high-altitude aircraft and are generally electrically driven rather than air driven, as in the case of the older type gyros, because of the loss of efficiency of the air-driven type at high altitudes. Attitude indicators have a knob that allows you to move the miniature airplane up or down to compensate for small deviations in the horizontal-line position.

The attitude indicator is more expensive than the turn and slip but allows the pilot to get an immediate picture of the plane's attitude. It can be used to establish a standard-rate turn, if necessary, without reference to the turn coordinator or turn and slip indicator, as will be shown.

An airplane's rate of turn depends on its velocity and amount of bank. For any airplane, the slower the

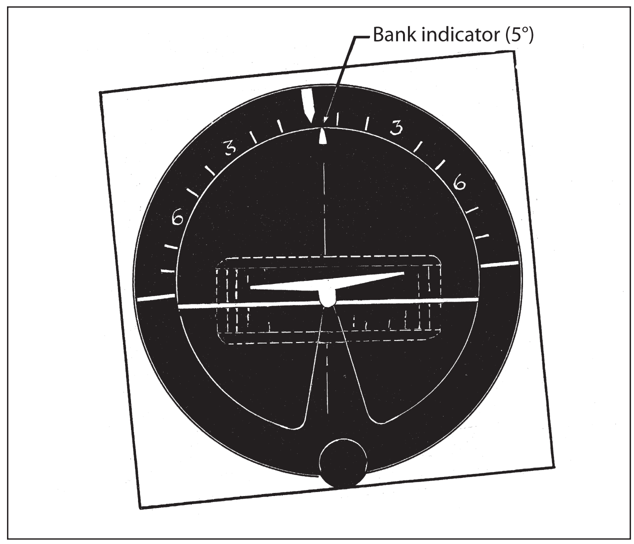


Figure 3-19. Attitude indicator. Shown is a nose-up, left-wing down (5° bank) attitude. Although it appears to indicate a shallow climbing turn to the left, a check with other instruments is needed to confirm this.

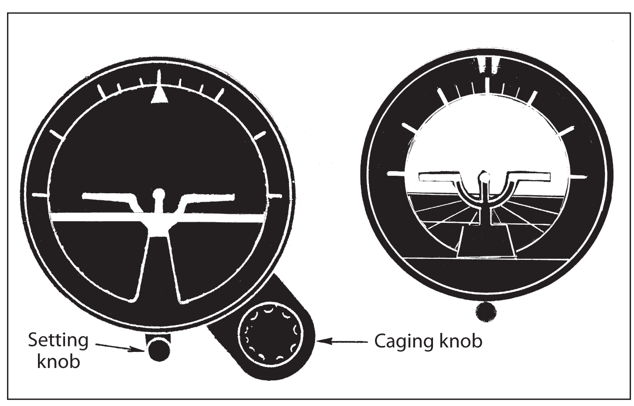


Figure 3-20. Attitude indicators (caging and noncaging types).

Turn and Slip | Turn Coordinator | Attitude Indicator

Figure 3-21. The turn and slip, turn coordinator, and attitude indicator indications in a standard-rate turn at 100K. Setting up the thumb rule for the bank angle only works for the balanced turn (no slip or skid).

velocity and the greater the angle of bank, the greater the rate of turn. This will be evident as soon as you begin flying and is probably so even now.

A good rule of thumb to find the amount of bank needed for a standard-rate turn at various airspeeds (mph) is to divide your airspeed by 10 and add 5 to the answer. For instance, airspeed = 150 ÷ 10 = 15; 15 + 5 = 20° bank required. This thumb rule is particularly accurate in the 100–200 mph range.

Figure 3-21 compares the indications of the turn and slip, turn coordinator, and attitude indicator in a standard-rate turn to the right at 100 K *true airspeed*. (True airspeed would be the proper one to use in the rule of thumb, but indicated or calibrated airspeed is okay for a quick result.)

A rule of thumb for finding the required bank for a standard-rate turn when you are working with knots is to divide the airspeed by 10 and multiply the result by 1½. As an example, at an airspeed of 156 K you'd get 15.6° (call it 16°). One and one-half times 16 is 24° required.

Heading Indicator

The heading indicator functions because of the gyro principle of "rigidity in space" as did the attitude indicator. In this case, however, the plane of rotation is vertical. The older heading indicator has a compass card or azimuth scale that is attached to the gyro gimbal and wheel. The wheel and card are fixed and, as in the case of the magnetic compass, the plane turns about them.

The heading indicator has no "brain" (magnet) that causes it to point to the Magnetic North Pole; it must be set to the heading indicated by the magnetic compass. The instrument should be set when the magnetic compass is reading correctly, and this is done in straight and level flight when the magnetic compass has "settled down."

You should check the heading indicator against the compass about every 15 minutes in flight. More about this in Chapter 25.

The advantage of the heading indicator is that it does not oscillate in rough weather and it gives a true reading during turns when the magnetic compass is erratic.

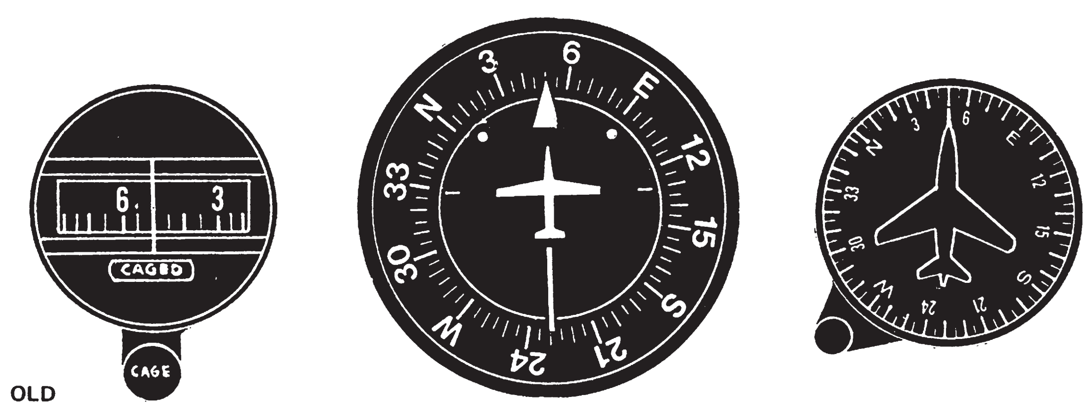


Figure 3-22. Three types of heading indicator presentations.

A caging/setting knob is used to cage the instrument for aerobatics or to set the proper heading.

A disadvantage of the older types of heading indicators is that they tumble when the limits of 55° nose up or down or 55° bank are reached. Newer heading indicators have higher limits of pitch and bank and have a resetting knob rather than a caging knob. Figure 3-22 compares the faces of the old and newer types.

More expensive gyros, such as are used by the military and airlines, are connected with a magnetic compass in such a way that this creep is automatically compensated for.

The greatest advantage of the heading indicator is that it allows you to turn directly to a heading without the allowance for lead or lag that is necessary with a magnetic compass.

Figure 3-23 shows the schematic of the engine-driven vacuum system of a popular trainer. The air filter is on the firewall under the instrument panel.

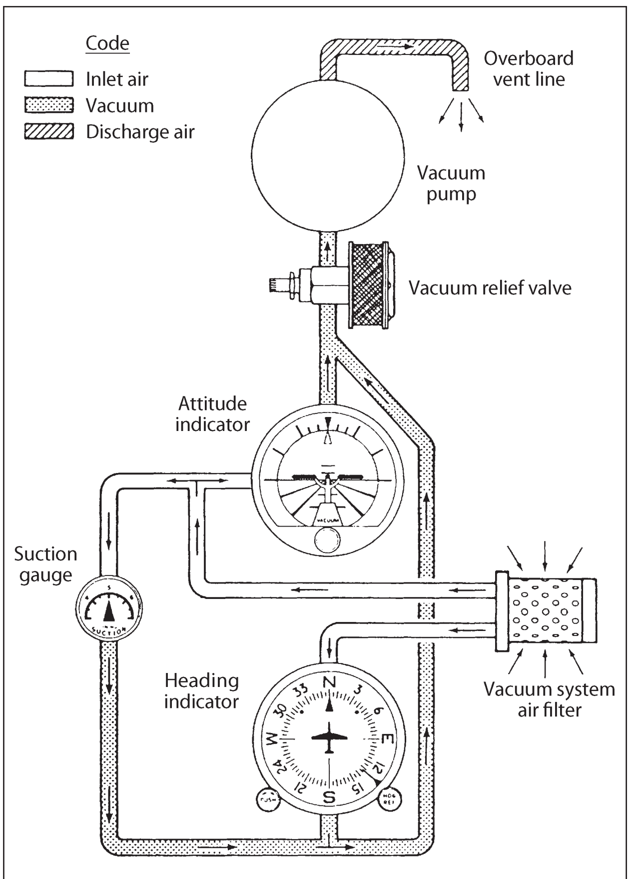


Figure 3-23. Engine-driven vacuum pump system.

Vertical Speed Indicator

This is an instrument that is useful in maintaining a constant rate of climb or descent.

It is a rate instrument and depends on a diaphragm for its operation, as does the altimeter. In the rate of climb indicator the diaphragm measures the change of pressure rather than the pressure itself, as the diaphragm in the altimeter does.

The diaphragm has a tube connecting it to the static port (*see* Figure 3-5), or the tube may just have access to the outside air pressure in the case of cheaper or lighter installations. This means that the inside of the diaphragm has the same pressure as the air surrounding the plane. Opening into the otherwise sealed instrument case is a capillary, or very small tube. This difference in the diaphragm and capillary tube sizes means a lag in the equalization of pressure in the air within the instrument case as the altitude (outside pressure) changes.

Figure 3-24 is a schematic diagram of a vertical speed indicator. As an example, suppose the plane is flying at a constant altitude. The pressure within the diaphragm is the same as that of the air surrounding it in the instrument case. The rate of climb is indicated as zero.

The plane is put into a glide or dive. Air pressure inside the diaphragm increases at the same rate as that of the surrounding air. However, because of the small size of the capillary tube, the pressure in the instrument case does not change at the same rate. In the case of a glide or dive, the diaphragm would expand—the

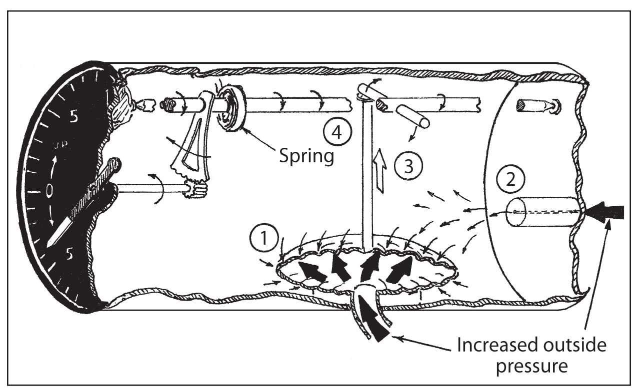


Figure 3-24. A simplified view of a vertical speed indicator. As the plane descends, outside pressure increases. The diaphragm expands immediately (1). Because of the small size of the capillary tube (2), pressure in the case is not increased at the same rate. The link pushes upward (3) rotating the shaft (4), which causes the needle to indicate 400 fpm down as shown. The spring helps return the needle to zero when pressures are equal and also acts as a dampener. The instrument here is shown proportionally longer than the actual rate of climb indicator so that the mechanism may be clearly seen.

amount of expansion depending on the difference of pressures. The diaphragm is mechanically linked to a hand, and the appropriate rate of descent, in hundreds (or thousands) of feet per minute (fpm), is read on the instrument face.

In a climb the pressure in the diaphragm decreases faster than that within the instrument case, and the needle will indicate an appropriate rate of climb. The standard rate of descent in instrument work is 500 fpm (Figure 3-25).

Because in a climb or dive the pressure in the case is always "behind" the diaphragm pressure, a certain amount of lag results. The instrument will still indicate a vertical speed for a short time after the plane is leveled off. For this reason the vertical speed indicator is not used to maintain altitude. On days when the air is bumpy, this lag is particularly noticeable. The vertical speed indicator is used, therefore, either when a constant rate of ascent or descent is needed or as a check of the plane's climb, dive, or glide rate. The more stable altimeter is used to maintain a constant altitude.

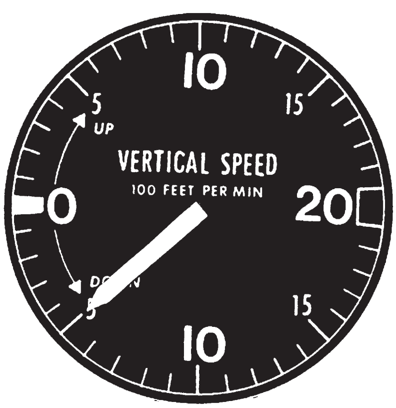


Figure 3-25. Standard rate of descent.

Summary of the Additional Instruments

Gyro instruments and the vertical speed indicator are not covered in detail as would be done in a training manual for an instrument rating. The calibrations and procedures used by instrument pilots are not covered for obvious reasons. For the non-instrument-qualified private pilot or the student, these instruments are to be used in an emergency only as a means of survival. Even the most expensive instruments cannot compensate for lack of preflight planning or poor headwork in flight.

Electrical System

Since most trainers these days have electrical systems for starting and for lights and radios, Figure 3-26 is included to give an idea of a simple system.

The battery stores electrical energy, and the engine-driven alternator (or generator) creates current and replenishes the battery, as necessary, as directed by the voltage regulator or alternator control unit.

The ammeter (item 15, Figure 3-1) indicates the flow of current, in amperes, from the alternator to the battery or from the battery to the electrical system. When the engine is operating and the master switch (item 28, Figure 3-1) is ON, the ammeter indicates the charging rate of the battery. If the alternator isn't working or if the load is too great, the ammeter will show the discharge rate of the battery.

Note in Figure 3-26 that the system has a split master (electrical) switch (upper left-hand corner). The right half of the switch (BAT) controls all electrical power

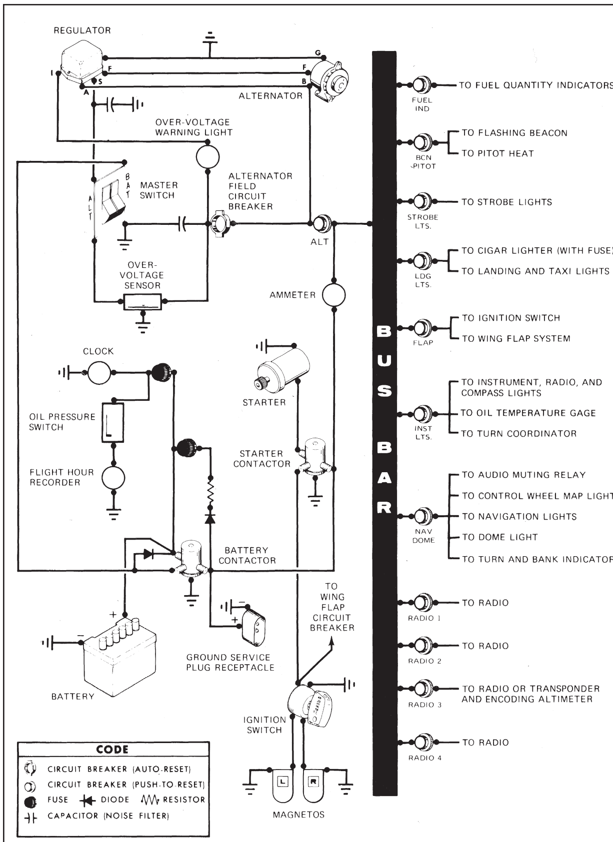


Figure 3-26. Electrical system. If you don't have a background in electricity, these diagrams can seem very complicated. Your job as pilot will be to know what system is affected by a loss of electrical power. You'll need to know what components are protected by circuit breakers or fuses and where the breakers (or fuses) are in the cockpit. This diagram shows the electrical items.

in the airplane. The left half (ALT) controls the alternator. For normal operations both switches should be ON so that the system (BAT) is working and the alternator is "replenishing" the electricity used by the various components, as is the case for your automobile (except the airplane doesn't depend on the battery/alternator for ignition, but more about this shortly). If the alternator started acting up, you'd turn it off and rely on the battery (for a while, anyway), conserving electricity by turning off all unnecessary electrical equipment. You should not, in this particular system, turn off the battery switch when the alternator is operating.

If the battery is completely dead, hand starting (propping) the airplane may get the engine running, but the alternator needs some electrical power to energize it to start charging. It won't be building up the battery, even after the engine is running. An outside source of electricity (with jumper cables, for instance) is necessary for beginning the charging process by the alternator. Let the pros at the airport do it.

Circuit breakers or fuses are installed to protect the electrical circuits (item 32, Figure 3-1). The circuit breakers "pop out" or the fuses burn out when an overload occurs, breaking the connection between the item causing the problem and the alternator-battery system. The circuit breakers may be reset, but a 2-minute cooling period is usually recommended. Most pilots will not reset a popped breaker unless it's needed for the safety of flight, and won't reset one of those if it trips after the first reset. You're just asking for a fire. For systems that utilize fuses, spares are sometimes carried in clips in the map compartment.

The ignition system is shown in Figure 3-26, but it is self-sustaining and independent of the alternator-battery system. An airplane engine does not need an alternator-battery system to operate. In fact, for many years most did not have one; the engine was started by hand. The magnetos are run by the engine and in turn furnish the spark for combustions—a sort of "you rub my back and I'll rub yours" arrangement that works very well. The magnetos will be covered again in following chapters.

Aircraft Documents

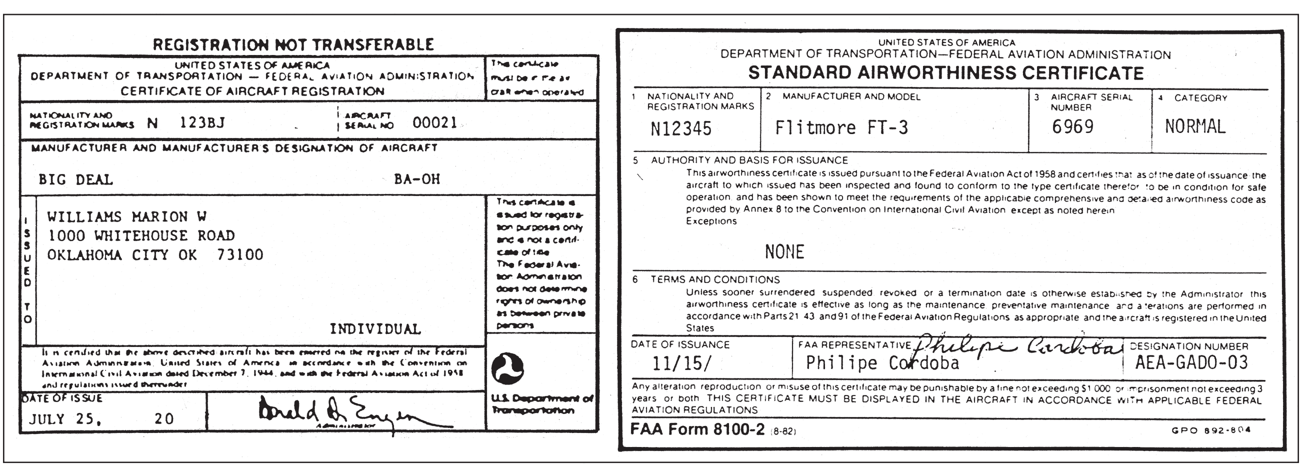
Every aircraft must carry three documents at all times in flight: (1) Certificate of Aircraft Registration or ownership, (2) Airworthiness Certificate (this must be displayed), and (3) Airplane Flight Manual or equivalent form containing an equipment list and limitations. Look in your plane and know where these documents are.

Certificate of Aircraft Registration

The Certificate of Aircraft Registration (Figure 3-27) contains the name and address of the owner, the aircraft manufacturer, model, registration number, and manufacturer's serial number. The registration certificate must be renewed every 3 years and when the plane changes owners.

Airworthiness Certificate

The Airworthiness Certificate (Figure 3-27) is a document showing that the airplane has met the safety requirements of the Federal Aviation Administration and is "airworthy." It remains in effect as long as the aircraft is maintained in accordance with the Federal Aviation Regulations. This means that required inspections or repairs are done and notice of this is entered in the aircraft and/or engine logbook.


REGISTRATION NOT TRANSFERABLE

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION — FEDERAL AVIATION ADMINISTRATION
CERTIFICATE OF AIRCRAFT REGISTRATION

NATIONALITY AND REGISTRATION MARKS N 123BJ
AIRCRAFT SERIAL NO 00021

MANUFACTURER AND MANUFACTURER'S DESIGNATION OF AIRCRAFT
BIG DEAL BA-OH

ISSUED TO
WILLIAMS MARION W
1000 WHITEHOUSE ROAD
OKLAHOMA CITY OK 73100
INDIVIDUAL

This certificate is issued for registration purposes only and is not a certificate of title. The Federal Aviation Administration does not determine rights of ownership as between private persons

It is certified that the above described aircraft has been entered on the register of the Federal Aviation Administration, United States of America, in accordance with the Convention on International Civil Aviation dated December 7, 1944, and with the Federal Aviation Act of 1958 and regulations issued thereunder

DATE OF ISSUE
JULY 25, 20

Administrator

U.S. Department of Transportation

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION—FEDERAL AVIATION ADMINISTRATION
STANDARD AIRWORTHINESS CERTIFICATE

1 NATIONALITY AND REGISTRATION MARKS	2 MANUFACTURER AND MODEL	3 AIRCRAFT SERIAL NUMBER	4 CATEGORY
N12345	Flitmore FT-3	6969	NORMAL

5 AUTHORITY AND BASIS FOR ISSUANCE
This airworthiness certificate is issued pursuant to the Federal Aviation Act of 1958 and certifies that as of the date of issuance the aircraft to which issued has been inspected and found to conform to the type certificate therefor to be in condition for safe operation and has been shown to meet the requirements of the applicable comprehensive and detailed airworthiness code as provided by Annex 8 to the Convention on International Civil Aviation except as noted herein
Exceptions
NONE

6 TERMS AND CONDITIONS
Unless sooner surrendered suspended revoked or a termination date is otherwise established by the Administrator this airworthiness certificate is effective as long as the maintenance preventative maintenance and alterations are performed in accordance with Parts 21 43 and 91 of the Federal Aviation Regulations as appropriate and the aircraft is registered in the United States

DATE OF ISSUANCE	FAA REPRESENTATIVE	DESIGNATION NUMBER
11/15/	Philipe Cordoba	AEA-GADO-03

Any alteration reproduction or misuse of this certificate may be punishable by a fine not exceeding $1 000 or imprisonment not exceeding 3 years or both THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE FEDERAL AVIATION REGULATIONS

FAA Form 8100-2 (8-82) GPO 892-804

Figure 3-27. The Certificate of Aircraft Registration and Airworthiness Certificate.

Airplane Flight Manual or *Pilot's Operating Handbook*

The *Pilot's Operating Handbooks* (POH) for general aviation airplanes are laid out as follows for standardization purposes:

Section 1: General—This is a general section and contains a three-view of the airplane and descriptive data on engine, propeller, fuel and oil, dimensions, and weights. It contains symbols, abbreviations, and terminology used in airplane performance.

Section 2: Limitations—This section includes airspeed limitations such as shown in Figure 3-28.

The primary airspeed limitations are given in knots and in both indicated and calibrated airspeeds (although some manufacturers furnish mph data as well), and the markings are in knots and indicated airspeeds.

The maneuvering speed, which is the maximum indicated airspeed at which the controls may be abruptly and fully deflected without overstressing the airplane, depends on the stall speed, which decreases as the airplane gets lighter. More about this in Chapter 23. Figure 3-29 shows the airspeeds from Figure 3-28 as they would appear on the airspeed indicator.

Included in this section are power plant limitations—engine rpm limits, maximum and minimum oil pressures, and maximum oil temperature and rpm range to be used (Figure 3-30). Weight and center of gravity limits are included for the particular airplane.

Maneuver and flight load factor limits (also to be discussed in Chapter 23) are listed, and operation limits (day and night, VFR, and IFR) are found here. Fuel limitations (usable and unusable fuel) and minimum fuel grades are covered in this section. An airplane may not be able to use some of the fuel in flight and this is listed as "unusable fuel." For example, one airplane has a total fuel capacity of 24 U.S. gallons with 22 U.S. gallons being available in flight (2 gallons unusable).

Section 3: Emergency procedures—Here are checklists for such things as engine failures at various

AIRSPEED LIMITATIONS

	SPEED	KCAS	KIAS	REMARKS
V_{NE}	Never Exceed Speed	141	141	Do not exceed this speed in any operation.
V_{NO}	Maximum Structural Cruising Speed	104	107	Do not exceed this speed except in smooth air, and then only with caution.
V_A	Maneuvering Speed: 1600 Pounds 1450 Pounds 1300 Pounds	 95 90 85	 97 93 88	Do not make full or abrupt control movements above this speed.
V_{FE}	Maximum Flap Extended Speed	89	85	Do not exceed this speed with flaps down.
	Maximum Window Open Speed	141	141	Do not exceed this speed with windows open.

AIRSPEED INDICATOR MARKINGS

MARKING	KIAS VALUE OR RANGE	SIGNIFICANCE
White Arc	42 - 85	Full Flap Operating Range. Lower limit is maximum weight V_{S_O} in landing configuration. Upper limit is maximum speed permissible with flaps extended.
Green Arc	47 - 107	Normal Operating Range. Lower limit is maximum weight V_S at most forward C.G. with flaps retracted. Upper limit is maximum structural cruising speed.
Yellow Arc	107 - 141	Operations must be conducted with caution and only in smooth air.
Red Line	141	Maximum speed for all operations.

Figure 3-28. Airspeed limitations and airspeed markings as given in a *Pilot's Operating Handbook*. Note the stall speeds (V_{S1} for flaps up, and V_{S0} for landing configuration) are given for maximum certificated weight. Compare the airspeed limitations with the indicator markings here. V_{NO} is the maximum structural cruising speed (or max speed for *Normal Operations*).

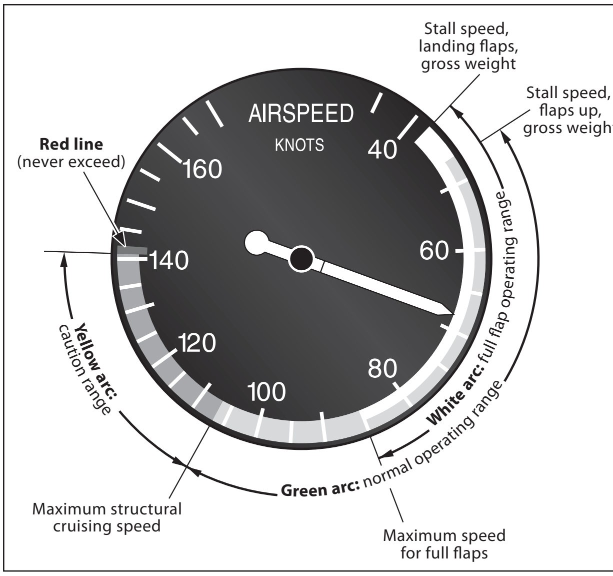


Figure 3-29. Important airspeed markings. For most airplanes manufactured before the 1976 models, the values were given in miles per hour and calibrated airspeed; 1976 and later models will have the airspeed markings as indicated airspeed in knots. (1K = 1.152 statute mph—*see* Chapter 19.) Your instructor will give you the word about this for the airplane you are using.

POWER PLANT INSTRUMENT MARKINGS

INSTRUMENT	RED LINE	GREEN ARC	RED LINE
	MINIMUM LIMIT	NORMAL OPERATING	MAXIMUM LIMIT
Tachometer	- - -	2000 - 2750 RPM	2750 RPM
Oil Temperature	- - -	100° - 240°F	240°F
Oil Pressure	10 psi	30 - 60 psi	100 psi

Figure 3-30. Power plant limitations.

portions of the flight; forced landings, including ditching; fires during start and in flight; icing; electrical power supply malfunctions; and airspeeds for safe operations.

There are amplified procedures for these “problems” including how to recover from inadvertently flying into instrument conditions and recovering after a vacuum system failure, spin recoveries, rough engine operations, and electrical problems.

Section 4: Normal procedures—This section also covers checklist procedures from preflight through climb, cruise, landing, and securing the airplane. It’s followed by amplified procedures of the same material. Recommended speeds for normal operation are summarized, as well as being given as part of the amplified procedures. Environmental systems for the airplane and other normal procedures are also included.

Section 5: Performance—Performance charts (takeoff, cruise, landing) with sample problems are included with range and endurance information, airspeed calibration, and stall speed charts.

Section 6: Weight and balance and equipment list—Airplane weighing procedures are given here, with a loading graph and an equipment list with weights and arms of the various airplane components.

Section 7: Airplane and systems descriptions—The airframe, with its control systems, is described and diagrammed. The landing gear, engine and engine controls, etc., are covered in this section. Also, fuel, brake, electrical, hydraulic, and instrument systems are laid out in detail. Additional systems such as oxygen, anti-icing, ventilation, heating, and avionics are covered here.

Section 8: Airplane handling, service, and maintenance—Here is the information you need for preventive maintenance, ground handling, servicing and cleaning, and care for that particular airplane.

Section 9: Supplements—This is devoted to covering optional systems with descriptions and operating procedures of the electronics, oxygen, and other nonrequired equipment. You should be well familiar with the *Pilot’s Operating Handbook* of your airplane.

Logbooks

The Federal Aviation Regulations require that the registered owner or operator keep a separate maintenance record for airframe, engine(s), and propeller(s).

Airplanes must have had an annual inspection within the preceding 12 calendar months to be legal. There are some exceptions for special flight permits or a progressive (continuing) inspection procedure, but the vast majority of airplanes fall under the requirements of an annual inspection. You might check with your instructor about your airplane. The annual inspection must be done, even if the airplane has not been flown during that time.

In addition, if the airplane is operated carrying persons for hire (charter, rental, flight instruction, etc.), it must have had an inspection within the past 100 hours of flying (tachometer time or other approved method of noting the time). The 100-hour limitation may be exceeded by not more than 10 hours if necessary to reach a place at which the inspection can be done. The excess time must be included in the next 100 hours of time in service.

If your airplane has had any major repairs or alterations since its manufacture, a copy or copies of the major repair and alteration form must be aboard the airplane (normally it’s attached to the weight and balance information for convenience). This lists the airplane make and model, registration number, manufacturer’s serial number, and the owner’s name and address; it may also have that particular airplane’s latest empty weight, the empty center of gravity location in inches from the datum, and the useful load of the plane. The useful load includes the weight of usable fuel, occupants, and baggage. The maximum weight minus the empty weight equals the useful load. (Use actual passenger weights.) The gas weight is 6 pounds per gallon, and the oil, $7\frac{1}{2}$ pounds per gallon. When you are loading the baggage compartment, do not exceed the placard weight, even if you have plenty of weight left before reaching the maximum for the airplane. You may overstress the compartment as well as adversely affect the position of the center of gravity of the plane. (Chapter 23 covers this subject in more detail.) Any major repairs or additions of equipment such as radios, etc., that would affect the position of the center of gravity are noted on this form.

On the back of the major repair and alteration form is a description of the work accomplished. The person authorized for such work signs the form and gives the date that the repair or alteration was completed.

The 100-hour inspection can be completed and signed by a certificated airframe and power plant mechanic, but the annual inspection must be supervised by an A and P mechanic or facility holding inspection authorization. If you get the 100 hours done by such mechanics or facilities, it can count as an annual inspection. If an annual inspection is done anytime in, say, the month of May (which means that it is good until the end of the following May) and it’s necessary to get a 100-hour inspection in August, this 100-hour inspection, if done by the same people who did the annual, can count as a new annual inspection—which means that the next annual is due by the end of the following *August*, not the next May. The inspectors will note the date and recorded tach time (or other flight time), and the type of inspection will be noted in the logbooks.

The logbooks are not required to be in the plane at all times, unlike the first three documents discussed, but they must be available to an FAA inspector if requested. This means that if you're operating away from the plane's normal base, it would be wise to take the logbooks with you.

Radio Equipment

The instructor may explain the use of the radio equipment before the first flight, particularly if you are flying from an airport with a control tower. You will have a chance to watch and listen to the instructor for the first few flights and will soon be asking for taxi instructions and takeoff and landing clearances yourself, under supervision. If you are flying from an airport where a radio is required, you might also look at Chapter 21 soon after you start flying.

Most small airports have a "UNICOM" or aeronautical advisory station for giving traffic information and wind and runway conditions to pilots operating in the vicinity of the airport. You may get an early start in the use of radio while operating out of an airport so equipped.

Glass Cockpit

Although systems vary, flat panel displays or electronic flight information systems (EFIS) usually consist of two electronic screens, one showing primary flight information (Primary Flight Display or PFD) and one showing navigation and engine information (Multi-Function Display or MFD). The flight information is usually derived from solid-state attitude reference units (aircraft attitude and acceleration), air data units (airspeed, altitude and rate of climb) and magnetometer (heading). Navigation data usually comes from a GPS receiver and is displayed on the multi-function second screen along with the engine instruments. Backup or standby instruments are included along with the 2 LCDs; these normally include a conventional airspeed indicator, mechanical attitude indicator, and an altimeter.

The PFD is not just a representation of the basic mechanical instruments, but the aircraft's attitude surrounded by the other flight information in various formats. Airspeed is often shown as a movable tape on the left side of the display, altitude as a tape on the right side next to a vertical speed scale with a moving pointer. The traditional "ball" indication can be shown as a movable base of the "sky-pointer" arrow that always points away from the ground. The base of the pointer slides out to show uncoordinated flight. Heading is sometimes shown on both the flight and navigation display.

Navigation data is often depicted as a moving map with aircraft position, weather information (either from onboard or downloaded radar), traffic, terrain and closest airports.

Advantages to this instrument system are excellent (or better) in-flight situational awareness and the ability to somewhat tailor the displayed information. Maintenance personnel are able to update the system software and more easily troubleshoot problems than with traditional instruments.

The complexity and flexibility of EFIS means a great deal of training should be accomplished on the ground. Using computer simulation or cockpit practice dramatically reduces frustration in-flight. For safety, a pilot must avoid the temptation of being "heads down"

Figure 3-31. Conventional "steam gauge" flight instruments (top) and glass cockpit PFD depiction of flight instruments.

for any length of time in flight or on the ground with the engine running. Transitioning to an aircraft with standard instruments and navigation may feel quite awkward after using EFIS.

Summary

Don't expect to have all the information in this chapter and the following four chapters down cold before you start flying. Read them over and then use them for review purposes after you've been introduced to the various subjects (the cockpit, preflight check, starting, and taxiing) by the instructor. This is a workbook and is intended to be used both before and as you fly. Remember, too, that your instructor and the *Pilot's Operating Handbook* will have recommendations as to what is best for your particular airplane and operating conditions.

As a review of the effects on non-standard temperatures on the accuracy of the altimeter as noted earlier in the chapter, take a look at Figure 3-32.

Figure 3-33 shows the effect of flying from a high-pressure area to a low-pressure area without resetting the altimeter. If you'd flown the constant 3,500 feet indicated altitude as in Figure 3-33, as the pressure gradually changed you'd be at a true altitude of only 3,100 feet. Remember "High to Low, Look Out Below."

For more-detailed information on the systems discussed in this chapter, read Appendix B in the back of this book.

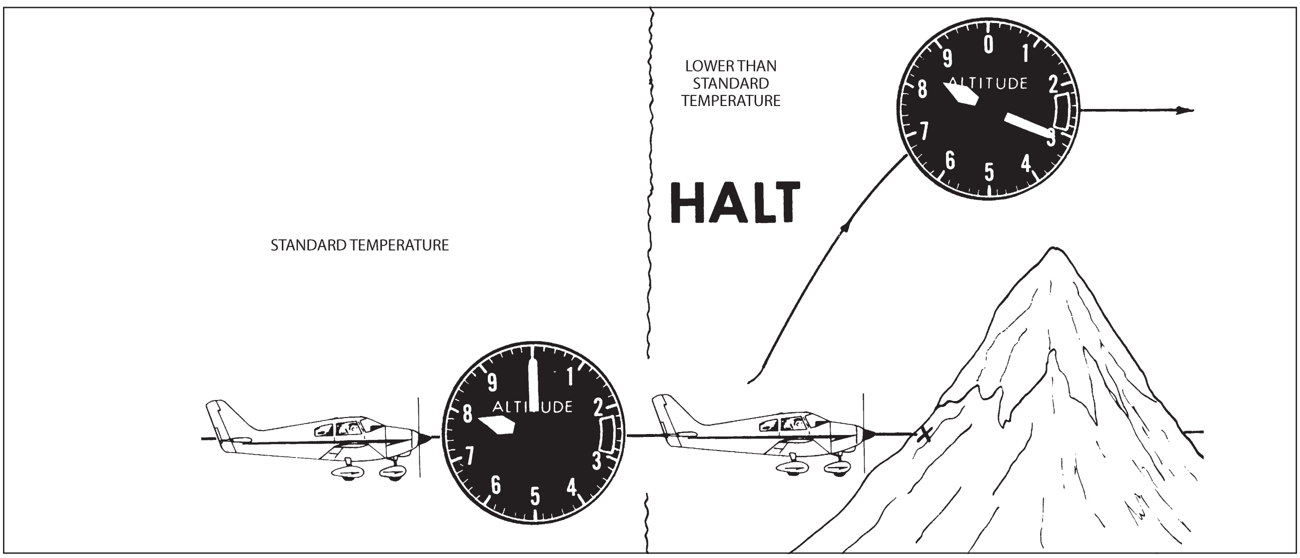


Figure 3-32. HALT. There is a **H**igh **A**ltimeter because of **L**ow **T**emperature. The altimeter *indicates* higher than the *actual* aircraft altitude. This will be of even more importance when you start working on that instrument rating and are concerned about traffic and terrain clearance when solely on instruments.

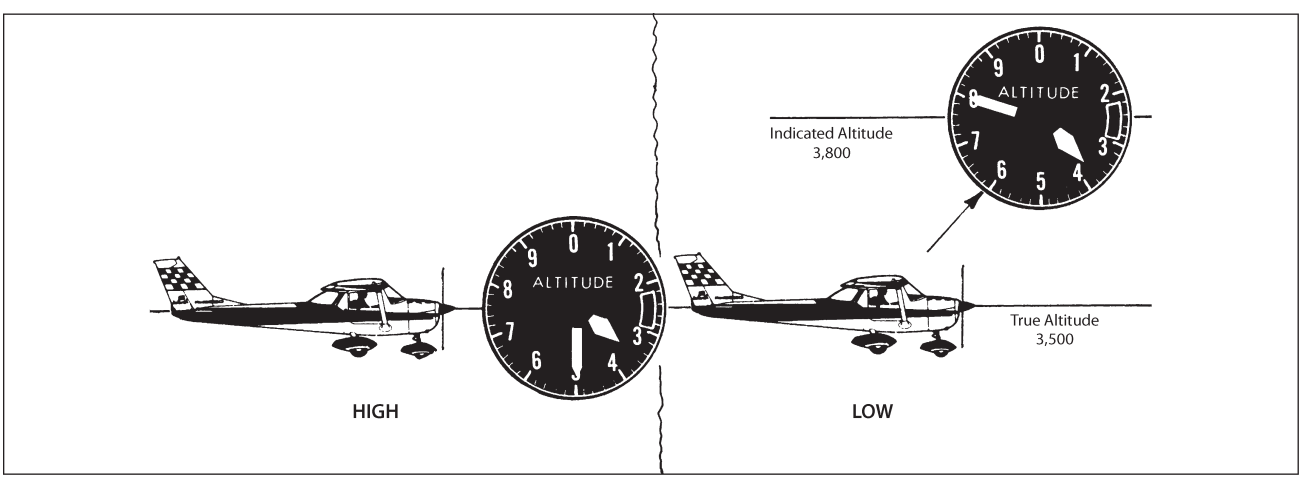


Figure 3-33. Flying from a high-pressure area to a low-pressure area without resetting the altimeter results in the altimeter indicating erroneously high.

4

Preflight Check

An organized check is the best way to start a flight. The best way to proceed is to make a clockwise (or counterclockwise, if you like) check starting at the cockpit and getting each item as you come to it. Don't be like Henry Schmotz, student pilot, who checked things as he thought of them. He'd check the prop, then the tailwheel and run back up front to look at the oil, etc. One day Henry was so confused that he forgot to check the wings (they were gone — the mechanic had taken them off for recovering) and tried to take off. He wound up in dire straits in the middle of a chicken farm right off the end of the runway. After he cleaned himself up, the first thing he did was to set up an organized preflight check and has had no trouble since.

One of the biggest problems the new student (and the more experienced pilot too) has is knowing what to look for in the preflight check. The first few times you look into the engine compartment and see that maze of wires, pipes, plates, etc., it seems that you wouldn't know if anything was out of place or not. The airplane engine assembly is compact and sealed. What's meant by this is: (1) There should be no evidence of excess *fluid leaks* (oil, brake fluid, or other fluids) in the compartment or on the engine. You may expect a certain small amount of oil, etc., to be present; but if in doubt about the "allowed amount," ask someone. (2) There should not be any loose wires or cables. Every wire or cable should be attached at both ends. If you find one dangling loosely, ask your instructor or a mechanic about it. Don't feel shy about asking questions.

Look at the inside of the bottom cowling to check for indications of fluid leaks. Some airplanes have cowlings that require a great deal of effort to remove — it's a bit impractical to remove what appears to be several hundred fine-threaded screws to check the engine before each flight. This is a bad design by the manufacturers, since the preflight check is definitely more than just checking the oil.

Discussed here (and shown in Figure 4-1) is a clockwise check of a typical high-wing general aviation airplane with side-by-side seating. The *Pilot's Operating Handbook* for your airplane has a suggested preflight check and you and your instructor may want to use it, referring to the *Handbook* or a checklist as you do the check. As you walk out to the plane, look at its general appearance; sometimes discrepancies can be seen better at a distance. Start the actual check at the cockpit.

Your instructor will point out the following items and note the things to look for on your particular airplane:

1. *Switch off*. You'll be checking the propeller so make sure the magneto switch is in the OFF position. This does not guarantee that the ignition is off, but you will double check the magnetos themselves later (in some airplanes). Better yet, the key should be *out* of the ignition, if the airplane is so equipped.

   Lower the flaps fully so that the hinges and operating rods may be examined more closely. If the flaps are electrical, before you turn the master switch ON make sure that the propeller area is clear. In rare cases, if the starter solenoid or other components are malfunctioning the starter might automatically engage of its own accord (the key is not even in the starter switch) and could be a real hazard to people or animals near the propeller. Be sure that the master switch is OFF after the flaps are down. Remove control locks.

   For some planes with an electric stall warning horn, you may want to turn the master (electrical) switch ON and move the tab on the wing to hear the horn. For other airplanes with a stall warning light (no horn) and the stall warning tab well out on the wing, have somebody else move it while you watch the light on the instrument panel. Make sure the master switch is OFF after either type of these checks is completed. Chapter 12 goes into more detail on the principle of stall warning devices.

   Nearly every nut on the airplane is safetied by safety wire, an elastic stop nut, or a cotter pin; there *are* a few exceptions, so if in doubt about a particular item, ask your instructor.

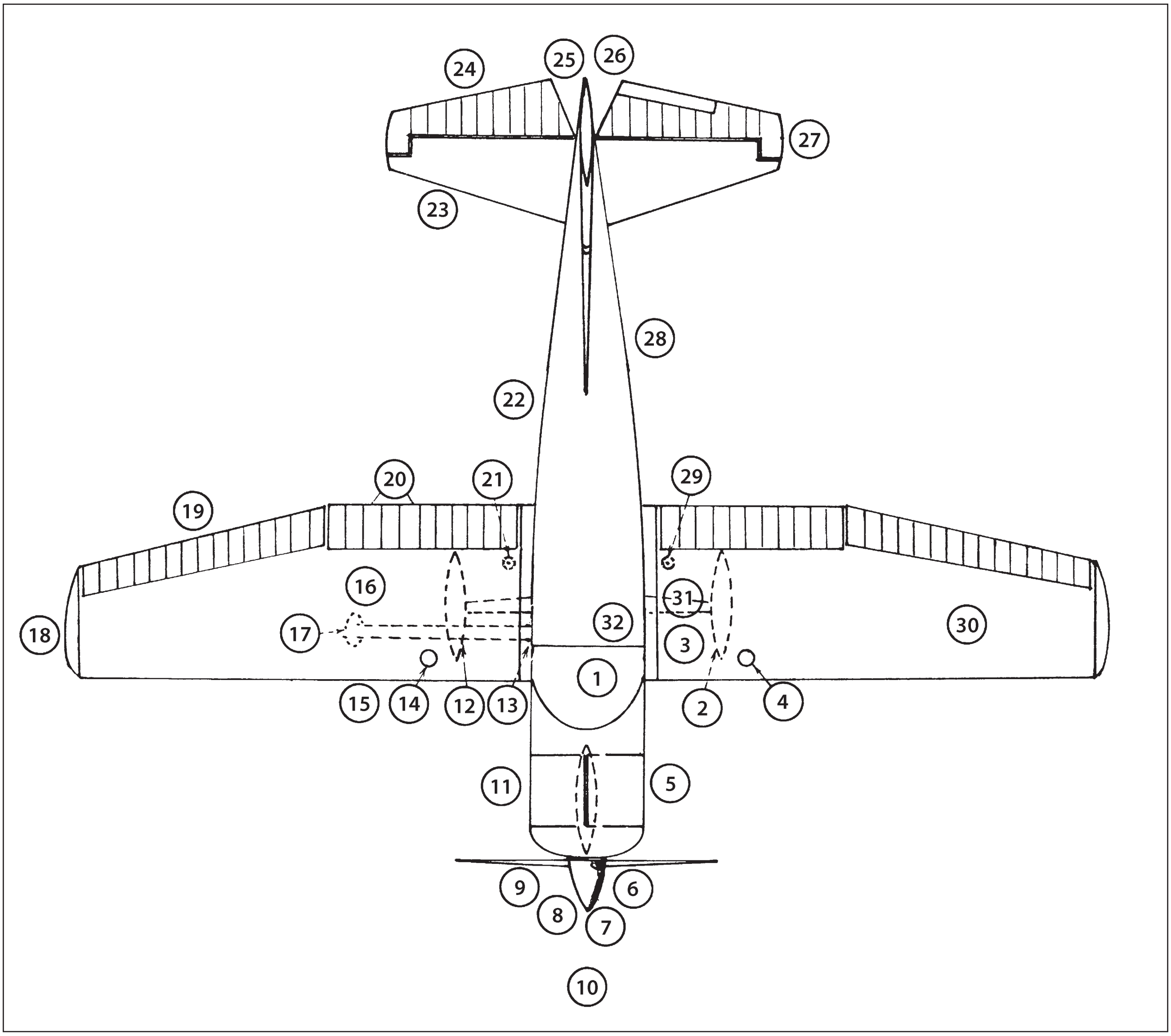


Figure 4-1. The preflight check.

2. *Tires and brakes*. The tires should be inspected for cord showing or for deep cuts. Roll the airplane a foot or so to see all sides of the tire. (Obviously, if this was a jet airliner it would be quite a job to roll it back and forth, but this book was written for lightplanes.) Check the brakes and brake lines for evidence of hydraulic leaks. Check the landing gear struts for damage and for proper inflation of the oleo strut if the plane has this type of shock absorber.
3. *Look for wrinkles* or any signs of strain or fracture along the sides of the fuselage near the landing gear. If the plane has been landed hard, this will be the first place to show it. Check for pulled or distorted rivets in a metal airplane.
4. If the aircraft has *wing tanks, visually* check the one on this side at this point; don't rely on tank gauges. You should drain fuel from the tank into a clear container (commercially available) to check for dirt and/or water. Hold the container up to the light (or sun) to get a better look. If contaminants are found, the fuel should be repeatedly drained and checked until it is clear. As a student pilot, however, the presence of foreign matter in the fuel should call for a discussion with your instructor and an extra check before flying. One disadvantage of holding the fuel up to the sky is that a full container of water or jet fuel (!) will appear blue, or the color of 100 Low Lead aviation fuel. Some instructors suggest that the container be held against the side of a white area of the fuselage to check its true color. Jet fuel, which can cause a fatal crash if used in a reciprocating engine, is straw-colored and smells like kerosene—a quick sniff of the fuel could avoid a bad problem.

It's best to fill the fuel tanks in the evening after the last flight; this keeps moisture from condensing on the sides of the tank during the cooler night temperatures and so decreases the possibility of water in the fuel.

Some pilots make up a tank dipstick from a 12-inch wooden ruler or wooden dowel so that they can get a look at the relative amount of fuel in the tank; they calibrate the sticks by filling the tanks a gallon or two at a time and marking them. One caution is that rubberized tanks may be punctured by a *sharp* dipstick. Calibrated fuel dipsticks are available for various airplanes through aviation supply houses.

5. *Engine compartment*. Open the cowling on the pilot's side and check:
   a. *Ignition lead ("leed") wires* for looseness or fraying. There are two magnetos, each firing its own set of plugs (two separate leads and plugs for each cylinder). The dual ignition system is for safety (the engine will run on either magneto alone), and each magneto will be checked during the pretakeoff check at the end of the runway. The magnetos are self-supporting ignition and have nothing to do with the battery. The battery-alternator system only furnishes power to the starter and other electrical equipment.
   b. *Each magneto* has a ground wire on it. When the ignition switch is turned to RIGHT or LEFT, the ground wire is electrically disconnected on that magneto, and it is no longer "grounded out" but is ON. You may do the same by a physical disconnection of the ground wire on a magneto. It may also vibrate loose, and that magneto will be ON even though the switch inside says OFF. It may vibrate off inside the magneto where it can't be seen, so it is best to always consider the prop as being "hot" even after checking the switch and ground wires. *Check both magneto ground wires at this point* if possible.
   c. *Look at the carburetor heat and cabin heat muffs for cracks*. These are shrouds around the exhaust that collect the heated air to be routed to the carburetor or cabin heater.

   Carburetor heat is necessary because float-type carburetors are very effective refrigerators. The temperature of the air entering the carburetor is lowered for two reasons: (1) The pressure of the mixture is lowered as it goes through the venturi (narrow part of the throat), which causes a drop in temperature. (2) The evaporation of the fuel causes a further drop in temperature. The result is that there may be a drop of up to 60°F below the outside temperature in the carburetor. If there is moisture in the air, these droplets may form ice on the sides of the venturi and on the jets, resulting in loss of power. If the situation gets bad enough, this can cause complete stoppage of the engine. That's where carburetor heat comes in. In a plane with a fixed-pitch prop (no manifold pressure gauge), the usual indication of icing is a dropping back of rpm with no change in throttle setting. There may be only a small amount of ice in the venturi and the effects may not be noticeable at full or cruising throttle, but when the throttle is closed to the idle position, all outside air may be shut out and the engine literally strangles. *So...before you close the throttle in the air, pull the carburetor heat; give it about 10 seconds to clear out any ice before pulling the throttle back.* (*See* item 21, Figure 3-1.)

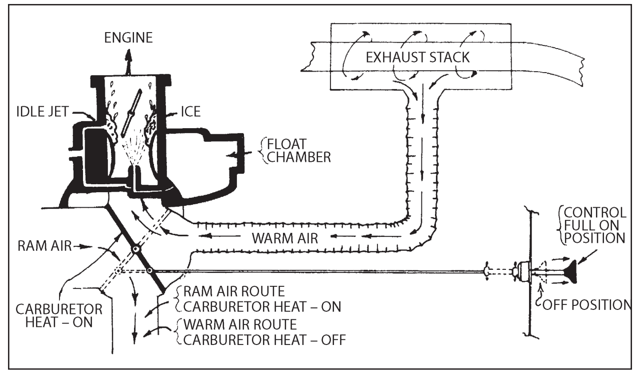


Figure 4-2. Carburetor heat system.

Carburetor icing boils down to this. It isn't the heat, or the lack of it, it's the humidity. At very low temperatures (say about 0°F) the air is so dry that carburetor icing is no problem. A wet cloudy day with a temperature of 50–70°F is the best condition for carburetor icing to occur.

As you pull the carburetor heat control knob in the cockpit, a butterfly valve is opened, allowing the prewarmed air from around the exhaust to mix with the outside air coming into the carburetor. This prevents ice from forming or melts ice already formed. (Figure 4-2 shows a *full* hot setting.)

Here are some of the indications of carburetor icing. The rpm starts creeping back slowly. Being a normal pilot, you'll probably open the throttle more to keep a constant rpm setting. A few minutes later (or sooner if icing conditions are bad), you'll have to open the throttle farther. Finally, realizing there is ice about, you'll pull the carburetor heat and get a shock. There'll be about a 100-rpm drop plus some soul-shaking reactions from the engine for a few seconds before the ice melts and power returns to near normal.

If there's a lot of ice, here's what happens. The ice melts and becomes a deluge of water into the engine. A little water helps compression (World War II fighters used water injection for bursts of power), but you can get too much of a good thing. Some pilots recommend partial heat in this situation, but the best answer is to use full heat as soon as signs of icing appear and continue using it as long as necessary, realizing that some power is lost because of the warmer, thinner air. When using full carb heat in cruise, leaning the mixture will regain most of the lost power. Check with your instructor about the best procedure for your airplane.

As part of the pretakeoff check, pull on the carburetor heat with the engine running at 1,800 rpm (or whatever rpm the manufacturer may ask for) and watch for a drop-off of about 100 rpm. It will vary from plane to plane, but this is about the normal drop. The heated air going into the engine is less dense than an equal volume of the outside cold air, and the engine will suffer a slight loss in power. In other words, if there's no drop-off, you're not getting heat to the carburetor, and it would be wise to find out what's up before flying.

The air coming through the carburetor heat system is not filtered, as the normal outside air coming to the carburetor is (*see* item 8), so it's possible to pick up dust and dirt when the carburetor heat is used on the ground. It's best to avoid extensive use of carburetor heat on the ground, particularly when taxiing, which may "stir up the dust."

Carburetor heat richens the mixture (the warmer air is less dense for the same weight of fuel going to the engine), so that using carburetor heat with the mixture full-rich at higher altitudes makes the engine run rough unless the mixture is leaned. Chapter 5 covers the use of the mixture control.

The fuel injection system is becoming more popular because of better fuel distribution to the cylinders and a lesser tendency to icing problems, but the carburetor will still be used for quite a while.

Most lightplane cabin heaters operate on the same principle of using hot air from around the exhausts. Pulling the cabin heat control opens a valve and allows the hot air to come into the cockpit. The effectiveness of the carburetor (and cabin) heat depends on the temperature of the air in the shroud(s), and this depends on the power being produced. If on a cold day you've been descending for some time at a low power setting with carb and cabin heats on and suddenly find that your feet are getting cold, you can be sure that the carburetor heat is becoming as ineffective as the cabin heat. Get plenty of power back on to assure effectiveness of the carb heat and also to warm the engine, or you shortly may have trouble getting the engine to respond. Larger planes will have the more efficient and more expensive gasoline cabin heaters.

d. The *fuel strainer drain* (not just for the fuel tanks) is located at the bottom of the airplane near the firewall. (The firewall separates the engine compartment from the passenger compartment.) Drain the fuel into a clear container, as noted in item 4, and check for contaminants. Some airplanes have more than one fuselage fuel drain.

e. While you're browsing in the *engine compartment*, your instructor will show you how the *engine accessories* should look. (Is that wire that's dangling there normal?) Since you probably don't have experience as an airplane mechanic, many things will just have to *look* right. Know the preflight check so thoroughly that anything not in its place will stick out like a sore thumb.

f. If the oil tank cap is on this side, *check the oil*. In most planes of this type, the oil is on the right, but don't count on it. The minimum allowable amount will vary from plane to plane. The instructor will give you this information. Most lightplanes of the 100-hp range hold 6 quarts and have a minimum flyable level of 4 quarts. Make sure the cap is secured after you've checked the oil. If you add oil, be sure it is the recommended grade or viscosity for the season and your airplane. Know whether your airplane uses ashless dispersant oil or straight mineral oil (Chapter 23).

g. *Check the alternator* for good wiring and connections (if you can see it; some airplanes have alternators that are pretty inaccessible without taking the cowling off). To repeat from Chapter 3, the alternator serves the same purpose as the one in your car; it keeps the system up for starting and operating the electrical accessories such as lights and radios and some engine and flight instruments as noted earlier. The battery box (and battery) is located in the engine compartment in some airplanes and should be checked for security here.

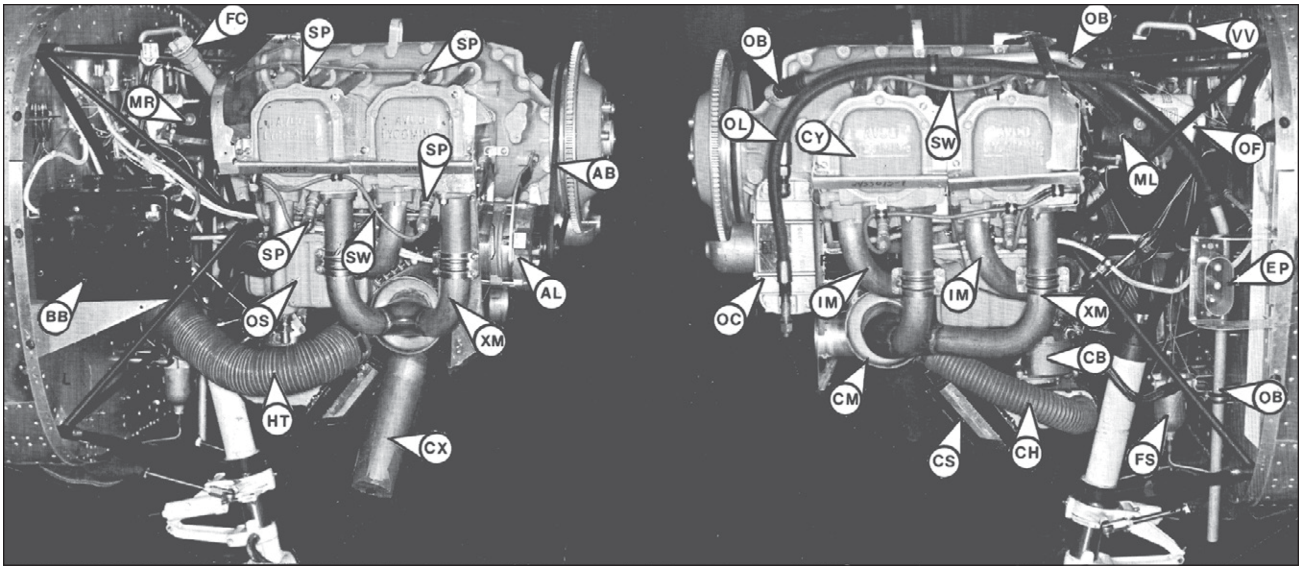


Figure 4-3. Components of the engine and systems of a current trainer as discussed in this chapter.

Figure 4-3 shows the components of a current trainer using a Lycoming 0-235 L2C engine that develops 110 brake horsepower at 2,550 rpm. (You might review Chapter 2 about brake and thrust horsepower.) The propeller has been removed.

Looking at the various parts:

AB—alternator drive belt.
AL—alternator.
BB—battery box.
CB—carburetor.
CH—carburetor heat hose from the muffler shroud (CM).
CS—carburetor intake screen.
CX—the common exhaust outlet or stack.
CY—one of the four cylinders.
EP—external electric power plug (for use on those cold mornings when the battery is dead; this is optional equipment).
FC—filler cap (oil) with dipstick attached.
FS—fuel strainer.
HT—hose from the muffler shroud for cabin heat.
IM—intake manifold (route of the fuel-air mixture from the carburetor to the cylinder, there are four of them here).
ML—magneto (left).
MR—magneto (right).
OB—oil breather line, which releases pressure created in the crankcase by the hot oil vapors (when you go out to the airplane after it has just shut down, you may see a small patch of light brown froth of oil or water on the ground under the outlet pipe. You can trace the route here from the front of the crankcase to the outlet opening). In the winter, the breather hose (sticking down below the cowling) should be checked to assure that the moisture, condensed to water, has not frozen over and sealed the outlet. If the outlet is sealed by ice, the pressures could build up in the crankcase and damage it.
OC—oil cooler. The oil is routed from the engine-driven oil pump through this small radiator to the engine and finally to the sump (it's slightly more complicated than that).
OF—oil filter.
OL—oil line from the oil cooler.
OS—the oil sump or oil storage tank.
SP—spark plugs. Each cylinder has two plugs.
SW—spark plug (ignition) wire or lead.
VV—vacuum system overboard vent line. (*See* Figure 3-23.)
XM—exhaust manifold.

It's unlikely that you'll get the cowling this much off of your airplane during any preflight check, but you might quietly watch the mechanics working on an engine in the hangar or look at an engine in the process of being overhauled. (Don't move any propellers; the mechanic might not appreciate it and it could be dangerous.)

h. Make sure the *cowling* is secured.
i. On some trainers the *vent for the static system* is located on the left side of the fuselage just behind the cowling. The static system instruments are, as you recall, the altimeter, rate of climb indicator, and airspeed indicator (which also needs a source of ram pressure, the pitot tube). The designers have located the static pressure orifice