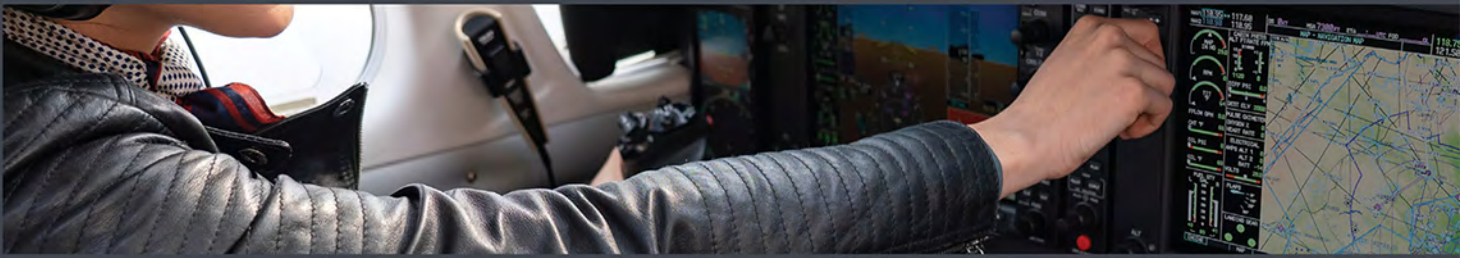
The Instrument Flight Manual

The Instrument Rating & Beyond



Based on the original text by

William K. Kershner

8th Edition | Edited by William C. Kershner

The Instrument Flight Manual

The Instrument Rating & Beyond

Based on the original text by

William K. Kershner

8th Edition | Edited by William C. Kershner

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 (and illustrator) 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.

The Instrument Flight Manual: The Instrument Rating & Beyond
Eighth Edition
William K. Kershner
Illustrated by the Author

First Edition published 1967, Iowa State University Press.
Eighth Edition published 2019 by Aviation Supplies & Academics, Inc.

Aviation Supplies & Academics, Inc.
7005 132nd Place SE
Newcastle, WA 98059-3153
asa@asa2fly.com | asa2fly.com

Cover photos: Front inset: Shutterstock ©RGtimeline and ©Nadezda Murmakova.
Front and back: iStock ©zxeynosure and ©sambrogio
Inside illustrations, for Eighth Edition: p. 2-15, courtesy Castleberry Instruments and Avionics;
pp. 2-27, 2-28, 2-29, courtesy Dynon Avionics. (Past edition photo credits and acknowledgments
listed on pp. R-3 through R-7.)

ASA-FM-INST-8
ISBN 978-1-61954-866-4

Contents

Part One

Airplane Performance and Basic Instrument Flying

Part Two

Navigation and Communications

Part Three

Planning the Instrument Flight

Part Four

The Instrument Flight

Part Five

Syllabus

Appendices

References and Printing History

2

Flight and Engine Instruments

The flight instruments will naturally now be of even greater interest and value than before, and it is extremely important that you understand how they work. Not only must you know how to fly by reference to them, but you will have to be aware of what you as a pilot must do to keep them operating properly and be able to recognize signs of impending instrument or system failure. This chapter will cover the flight and other instruments of utmost importance to the instrument pilot. For instance, you know that the attitude indicator is one of the most important flight instruments, but to date you have probably paid very little attention to the suction gauge, which can give warning of possible problems with the attitude indicator and other vacuum-driven instruments. The ammeter will also be of added importance; an electrical failure while flying under instrument conditions would pose many more problems than if you lost the electrically driven flight instruments and radios during VFR operations. An electrical failure, for instance, *could* cause you to lose the airspeed indicator in icing conditions.

Required Instruments and Equipment (Paraphrased)

Visual Flight Rules (Day)

For flying VFR (day) the airplane is required to have the following instruments and equipment (14 CFR Part 91):

1. Airspeed indicator.
2. Altimeter.
3. Magnetic direction indicator.
4. Tachometer for each engine.
5. Oil pressure gauge for each engine using pressure system.
6. Temperature gauge for each liquid-cooled engine.
7. Oil temperature gauge for each air-cooled engine.
8. Manifold pressure gauge for each altitude engine.
9. Fuel gauge indicating the quantity of fuel in each tank.
10. Landing gear position indicator if the aircraft has retractable landing gear.
11. For new airplanes (after 1996) an approved red or white anti-collision light system. If any light fails, you may continue to a stop where repairs can be made.
12. An aircraft for hire, flying "over-water," must have flotation devices readily available for each occupant. At least one approved flare must also be carried onboard the aircraft.
13. An approved safety belt for each occupant who has reached his/her 2nd birthday.
14. For small civil airplanes manufactured after July 18, 1978, an approved shoulder harness for each front seat.

Visual Flight Rules (Night)

For VFR flight at night, the following instruments and equipment are required in addition to those specified for VFR day flying:

1. Approved position lights.
2. Approved red or white anti-collision light system. If any light fails, you may continue to a stop where repairs can be made.
3. If the aircraft is operated for hire, one electric landing light.
4. An adequate source of electrical energy for all installed electrical and radio equipment.
5. One spare set of fuses or three spare fuses of each kind required (if your airplane has fuses).

It's interesting to note that, based on the required equipment, you can legally fly VFR at night with visibilities down to 3 statute miles in an airplane with no attitude indicator, no turn and bank (or turn coordinator) and no heading indicator other than the magnetic compass. If there is no visible horizon, spatial disorientation could be a real problem.

Instrument Flight Rules

For IFR flight the following instruments and equipment are required in addition to those specified for VFR day and VFR night flying:

1. Two-way radio communications system and navigational equipment appropriate for the ground facilities to be used.
2. Gyroscopic rate of turn indicator except on large airplanes with a third attitude instrument system usable through flight attitudes of 360° of pitch and roll and installed in accordance with 14 CFR §121.305(j).
3. Slip-skid indicator.
4. Sensitive altimeter adjustable for barometric pressure.
5. A clock displaying hours, minutes, and seconds with a sweep-second pointer or digital presentation.
6. Generator or alternator of adequate capacity (VFR night flight could have used a battery).
7. Gyroscopic pitch and bank indicator (artificial horizon).
8. Gyroscopic direction indicator (directional gyro or equivalent).

The above equipment lists are just a quick rundown of the requirements. 14 CFR §91.205 has all the details and exceptions laid out in FAR-language for your reading pleasure. Always have a current copy of the FAR/AIM available in your library (whether book or computer form).

Pitot-Static Instruments

These are the flight instruments that indicate air pressure or changes in pressure and include the airspeed indicator, altimeter, and rate of climb (or vertical speed) indicator. All three require static pressure, but only the airspeed indicator requires pitot (dynamic) pressure as well.

Airspeed Indicator

The airspeed indicator is an air pressure gauge calibrated to read in miles per hour or knots rather than pounds per square foot (psf). The airspeed system is made up of the pitot and static tubes and the airspeed indicator itself. As the airplane moves through the air, the relative wind exerts an impact pressure (or dynamic pressure) in the pitot tube, which expands a diaphragm linked to an indicating hand (Figure 2-1).

In addition to the dynamic pressure, static air pressure also exists in the pitot tube. As shown in Figure 2-1, the diaphragm contains both dynamic *and* static pressures. The static tube allows the static pressure to enter the instrument *case* so that these two static pressures cancel each other as far as the diaphragm is concerned; it expands only as a function of the dynamic pressure.

Dynamic pressure, sometimes called “q,” has the equation $(\rho/2)(V^2)$ where ρ (pronounced rho) is the air density in slugs per cubic foot, and V is the *true* velocity of the air in feet per second (fps). A slug is a unit of mass and may be found by dividing the weight of an object by the acceleration of gravity (32.2 fps/sec). Hence, a 161-pound man will have a mass of 5 slugs (161/32.2 = 5) regardless of the planet he is visiting. Note: It’s best not to use the term “slugs” when describing your significant other.

Realizing that the dynamic pressure is made up of the combination of one-half the density *times* the true speed (squared) of the air particles, you can see that a calibrated airspeed (CAS) of 150 knots could result either from high density and comparatively low speed of the air or a lower density and higher true airspeed. The density of the air at sea level is 0.002378 slugs/ft^3 (about 1/420th), and at a calibrated airspeed of 150 knots CAS would also be the true airspeed at *sea level standard conditions* (29.92 in. of mercury pressure at 59°F, or 15°C). The airspeed indicator cannot compensate for density change; it can only indicate the combination of density *and* velocity of the air.

At 10,000 feet the air density is only about ¾ of that at sea level; hence, if the plane has a CAS of 150 knots at that altitude, it is meeting the fewer air particles at a higher speed than was done at sea level in order to get the same dynamic pressure (CAS). If you are interested in the mathematics of the problem, the following is presented:

$$\text{Dynamic pressure (psf)} = \frac{\rho}{2}(V^2)$$

At sea level V = 150 knots = 254 fps

$$\text{Dynamic pressure} = \frac{0.002378}{2} \times (254)^2$$

$$= 76.3 \text{ psf}$$

A rule of thumb for finding dynamic pressure in pounds for various airspeeds is

$$\text{psf} = \frac{V^2 \text{ (knots)}}{295}$$

Using the earlier example of 150 knots, the answer would be

$$\frac{(150)^2}{295} = \frac{22{,}500}{295} = 76.27 \text{ psf (call it 76.3)}$$

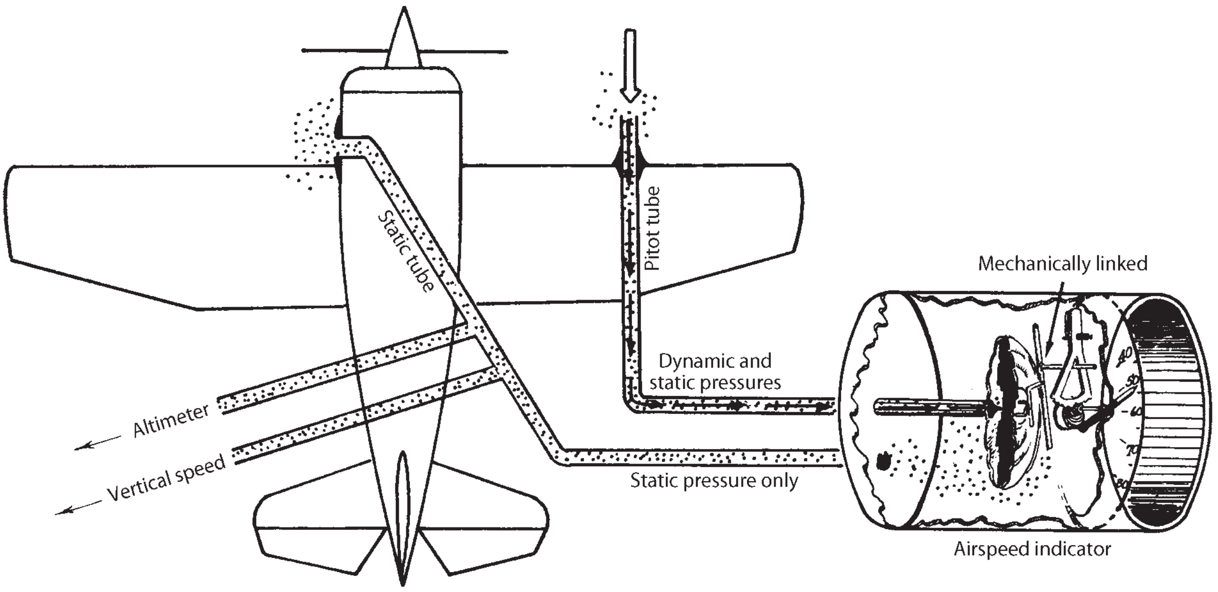


Figure 2-1. Airspeed indicator.

At 10,000 feet the standard air density is 0.001756 slugs/ft^3. Since the airplane has a CAS of 150 knots at 10,000 feet, the dynamic pressure is also 76.3 psf, and the true airspeed or true relative speed of the air can be found by solving for V as follows:

$$76.3 = \frac{0.001756}{2} \times V^2$$

$$V^2 = \frac{152.6}{0.001756}\,;\ V = \sqrt{\frac{152.6}{0.001756}}$$

V = 295 fps, or 175 knots

You do this type of calculation with your computer (whether you know it or not). You can check the above with your computer (the standard temperature at 10,000 feet is -5°C). You don't work with feet per second, however. You'll note that an indicated (or rather calibrated) airspeed of 150 knots at 10,000 feet density-altitude gives a true airspeed of 175 knots (174+).

In the illustration, it was assumed that the airspeed indicator was giving you the exact, straight story; this is not always the case. On your computer you are working with calibrated airspeed (CAS), which is the indicated airspeed (IAS) corrected for errors in the airspeed system (includes errors in the instrument plus errors in the pitot-static system, normally called position and/or installation errors). Your airplane may have an airspeed correction table that allows the correcting of IAS to CAS. In the majority of cases in practical application for smaller airplanes, airspeed system error is ignored and IAS is assumed to equal CAS in the cruise range. At low speeds near the stall, however, the difference between IAS and CAS can be 10 knots or more.

Figure 2-2 is a typical airspeed calibration chart for the normal static source. More about the alternate static source later.

Another term used is *equivalent airspeed* (EAS), and this is CAS corrected for compressibility effects. This is not of consequence below 250 knots and 10,000 feet, so it's not likely that you would need a compressibility correction table for your present work. Normally, your corrective steps will be IAS to CAS to TAS (true airspeed). If you have no correction card for instrument error, it will be IAS to TAS. If you are operating at altitudes and speeds where compressibility effects exist, note that the full number of steps would be IAS to CAS to EAS to TAS. The problem is that the static air in the pitot tube is being packed (compressed) and gives a high reading (remember that the pitot tube is measuring *both* dynamic *and* static pressures), so the effect is,

Airspeed Calibration
Normal Static Source

CONDITION:
Power required for level flight or maximum rated RPM dive.

FLAPS UP												
KIAS	50	60	70	80	90	100	110	120	130	140	150	160
KCAS	56	62	70	79	89	98	107	117	126	135	145	154
FLAPS 10°												
KIAS	40	50	60	70	80	90	100	110	---	---	---	---
KCAS	49	55	62	70	79	89	98	108	---	---	---	---
FLAPS 30°												
KIAS	40	50	60	70	80	85	---	---	---	---	---	---
KCAS	47	53	61	70	80	84	---	---	---	---	---	---

Figure 2-2. Airspeed calibration chart (normal static source).

as far as the airspeed indication is concerned, that of a higher dynamic pressure than actually exists. In other words, the CAS is higher than it should be, and computing for EAS gives the true picture.

Airspeed Indicator Markings

The FAA requires that the airspeed indicator be marked for various important speeds and speed ranges (Figure 2-3 shows the required markings):

Red line—Never exceed speed (V_{NE}). This speed should not be exceeded at any time.

Yellow arc—Caution range. Strong vertical gusts could damage the airplane in this speed range; therefore, it is best to refrain from flying in this range when encountering turbulence of any intensity. The caution range starts at the maximum structural cruising speed (V_{NO}) and ends at V_{NE}.

Green arc—Normal operating range. The airspeed at the lower end of this arc is the flaps-up, gear-up, power-off (wings-level, 1 g) stall speed at gross weight, V_{S1}. For most airplanes the landing gear position (full up or full down) has little or no effect on stall speed. The upper end of the green arc is the maximum indicated airspeed (V_{NO}) where no structural damage would occur in moderate vertical gust conditions (30 fps).

White arc—The flap operating range. The lower limit is the power-off stall speed (V_{S0}) with recommended landing flaps (might not be full flaps) at gross weight (gear extended and cowl flaps closed), and the upper limit is the maximum flap extended speed (full flaps).

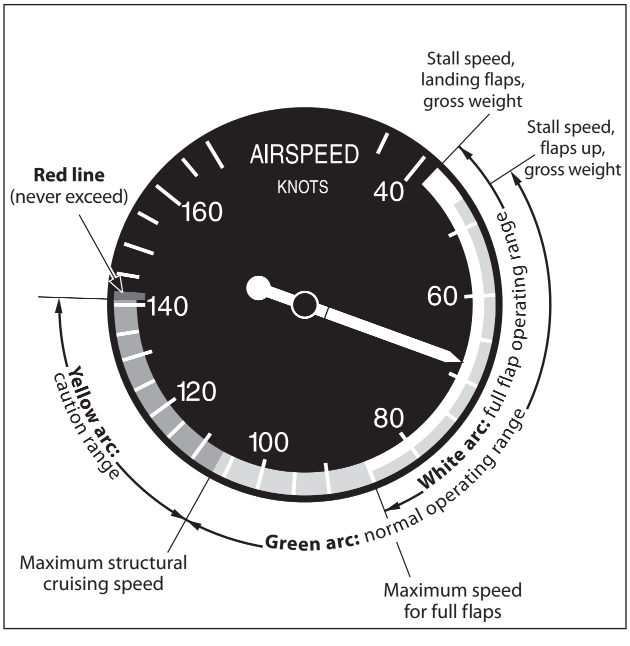


Figure 2-3. Airspeed indicator markings.

Older airplanes have the airspeed indicator markings as *calibrated* airspeed in miles per hour or knots. Newer airplanes will have the airspeed markings as *indicated* airspeed in knots. As a general rule, 1976 model (and later) airspeed indicators will be marked in knots of IAS, but you should confirm this in the *Pilot's Operating Handbook (POH)* or *Airplane Flight Manual.* (More about the *POH* at the end of this chapter.)

Altimeter

The altimeter (Figure 2-4) is the most important of the three instruments of the pitot-static group as far as instrument flying is concerned. It is an aneroid barometer calibrated to read in feet instead of inches of mercury. Its job is to measure the static pressure (or ambient pressure as it is sometimes called) and register this fact in terms of feet or thousands of feet.

The altimeter has an opening that allows static (outside) pressure to enter the otherwise sealed case. A series of sealed diaphragms or "aneroid wafers" within the case are mechanically linked to the three indicating hands. Since the wafers are sealed, they retain a constant internal "pressure" and expand or contract in response to the changing atmospheric pressure surrounding them in the case. As the aircraft climbs, the atmospheric pressure inside the instrument case decreases and the sealed wafers expand; this is duly noted by the indicating hands as an increase in altitude.

Standard sea level pressure is 29.92 inches of mercury, and the standard sea level temperature is 15°C, or 59°F. The altimeter is calibrated for this condition, and any change in local pressure must be corrected by the pilot. This is done by using the setting knob to set the

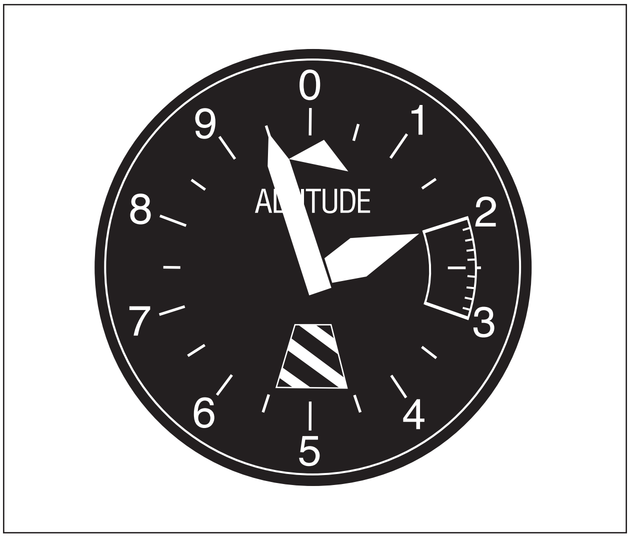


Figure 2-4. Altimeter. The 10,000-ft indicator (small wide triangle) and the hatched low-altitude warning flag won't be shown in the exercises that follow in this book.

proper barometric pressure (corrected to sea level) in the setting window. For instance, a station at an elevation of 670 feet above sea level has an *actual* barometric pressure reading of 29.45 in. of mercury according to its barometer. Since the pressure drop is 1.06 inches of mercury for the first 1,000 feet above sea level, an addition of 0.71 inches to the actual reading of 29.45 will correct the pressure to the sea level value of 30.16 inches of mercury. This, of course, assumes that the pressure drop is standard. This is the normal assumption and is accurate enough for *indicated* altitude.

There are several altitudes that will be of interest to you:

Indicated altitude is the altitude read when the altimeter is set to the local barometric pressure corrected to sea level as just mentioned.

True altitude is the height above sea level (MSL).

Absolute altitude is the height above the terrain (AGL).

Pressure altitude is the altitude read when the altimeter is set to 29.92. This indication shows what your altitude would be if the altimeter setting was 29.92, if it was a standard-pressure day at sea level.

Density-altitude is the pressure altitude computed with temperature; it is the altitude that dictates your aircraft's performance (or lack thereof). If you know your density-altitude, air density can be found using tables and the airplane performance can be calculated. You go through this step every time you use a computer to find the true airspeed. You use the pressure altitude and the outside air temperature (OAT) at that altitude to get the true airspeed. Usually, there's not enough difference in pressure altitude and indicated altitude to make it worthwhile to set up 29.92 in the setting window, so the usual procedure is to use the *indicated* altitude and OAT.

The fact that the computer used pressure altitude and temperature to obtain density-altitude in finding true airspeed didn't mean much, since you were only interested in the final result. You may not even have been aware that you were working with density-altitude during the process. Most computers also allow you to read the density-altitude directly by setting up pressure altitude and temperature. This is handy in figuring the performance of your airplane for a high-altitude and/or high-temperature takeoff or landing. The *POH* gives graphs or figures for takeoff and landing performance at the various density-altitudes. After finding your density-altitude, you can find your predicted performance in the *POH.* The manufacturer sometimes furnishes conversion charts with the *POH* (Figure 2-5).

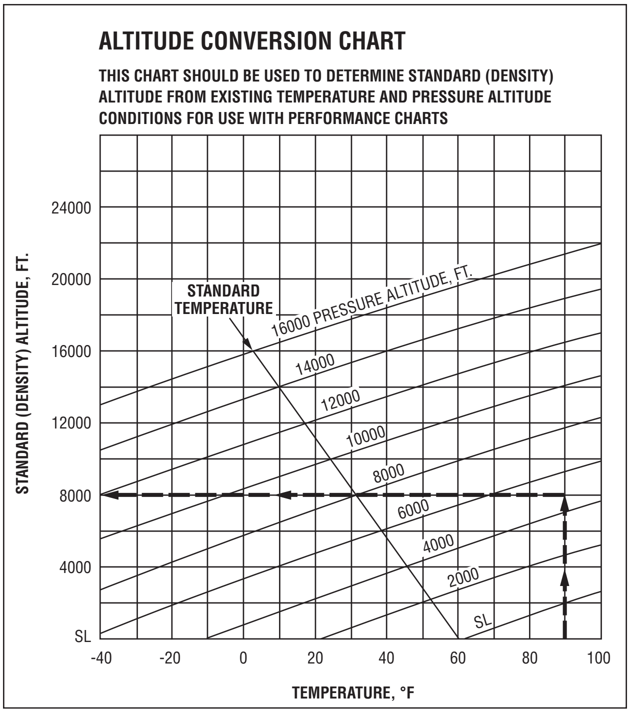


Figure 2-5. Altitude conversion chart. Move up the 90° line until the 5,000-ft pressure altitude is reached; directly across from this point is the standard (density) altitude for that combination (8,000 feet). (Courtesy of Piper Aircraft)

Suppose you are at a pressure altitude of 5,000 feet, and the outside air temperature is 90°F. Using the conversion chart, you see that your density-altitude is 8,000 feet (Figure 2-5). Looking at the takeoff curves for your airplane, you can find your expected performance at that altitude.

You and other pilots fly *indicated altitude.* When you're flying cross-country, you will have no idea of your exact altitude above the terrain (although over level country you can check airport elevations in your area, subtract this from your indicated altitude, and have a ballpark figure). Over mountainous terrain, this won't work, since the contours change too abruptly for you to keep up with them. As you fly, you'll get altimeter settings from various ground stations; keep up-to-date on pressure changes so your indicated altitude will be correct.

The use of indicated altitude for all planes makes good sense in that all pilots are using sea level as a base point, and proper assigned altitude separation results.

Altimeter Errors

Instrument or *system error*—If you set the current barometric pressure (corrected to sea level) for your airport, the altimeter should indicate the field elevation when you're on the ground. 14 CFR Part 91 specifies that airplanes operating in controlled airspace (IFR) must have had each static pressure system and altimeter instrument tested by the manufacturer or an FAA-approved repair station within the past 24 calendar months.

Pressure changes—When you fly from a high-pressure area into a low-pressure area, the altimeter "thinks" you have climbed and will register accordingly—even if you haven't changed altitude. You will see this and fly the plane down to the "correct altitude" and will actually be low. (This is a gradual process, and you will be easing down over a period of time to maintain what is the "correct altitude.") When you fly from a low- to a high-pressure area, the altimeter thinks you've let down to a lower altitude and registers too low. A good way to remember (although you can certainly reason it out each time) is: HLH—High to Low, altimeter reads High. LHL—Low to High, altimeter reads Low. (High to Low—look out below!)

You can see that it is worse to fly from a high-pressure to a low-pressure area as far as terrain clearance is concerned. Double-check altimeter settings as you fly IFR en route.

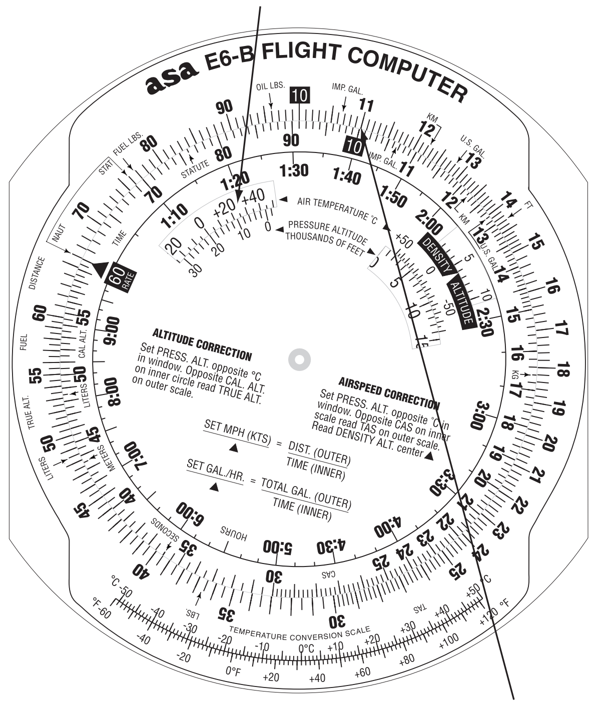
Temperature errors—The equation of state, which shows the relationship between pressure, density, and temperature of the atmosphere, notes that atmospheric pressure is proportional to the temperature. If the temperature is above normal, the pressure will be higher than normal (constant density). Therefore, if you are flying at a certain indicated altitude and the temperature is higher than normal, the pressure at your altitude is higher than normal. The altimeter registers *lower* than your *true* altitude. If the temperature is lower, the pressure is lower and the altimeter will register accordingly—*low temperature, altimeter reads high.*

You might remember it this way, using the letters H and L as in pressure change: Temperature High, altimeter reads Low—HL. Temperature Low, altimeter reads High—LH. Or maybe it's easier to remember HALT (High Altimeter because of Low Temperature).

For both temperature *and* pressure, remember "from High to Low, look out below." The best thing, however, is to know that higher temperature means higher pressure (and vice versa) at altitude and reason it out from there.

The temperature error is zero at sea level (or at the elevation of the station at which the setting is obtained) and increases with altitude so that the error could easily be 500–600 feet at the 10,000-ft level. In other words, you can have this error at altitude even if the altimeter reads correctly at sea level. Temperature error can be found with a computer, as shown in Figure 2-6. For indicated altitude this error is neglected; but it makes a good question for an instrument rating written exam or practical test, so keep it in mind.

1. Set outside air temperature (22°C) opposite pressure altitude (10,000 ft)



2. Opposite pressure altitude (inner ring), read corrected altitude (11,000 ft)

Figure 2-6. Correcting the altimeter for temperature errors.

These errors (particularly temperature errors, which are normally ignored) affect everybody in that area (though slightly differently for different altitudes), so that the altitude separation is still no problem. Temperature errors could cause problems as far as terrain clearance is concerned, however.

A final altimeter note: For computer work you are told to use the *pressure altitude* to find the true airspeed. For practical work, use *indicated altitude* (current sea level setting) for true airspeed computations. Remember that the TAS increases about 2% per 1,000 feet, so the most you will be off will be 2%. That is, your sea level altimeter setting could possibly be 28.92 or 30.92, but this is extremely unlikely. So...*assume that a total error of no more than 1% will be introduced by using indicated altitude.* For a 200-knot airplane, this means you could be 2 knots off true airspeed. But the instrument error or your error in reading the instrument could be this much.

As you progress in your instrument flying to heavier and more complex equipment, you'll use altitude indicators such as encoding altimeters (used with the transponder) and radar altimeters (which give absolute altitude readings). These will be covered in more detail in later chapters as their use is introduced.

Rate of Climb or Vertical Speed Indicator (VSI)

Like the altimeter, the VSI has a diaphragm. But unlike the altimeter, it measures the *rate of change* of pressure rather than the pressure itself.

The diaphragm has a tube connecting it to the static tube of the airspeed indicator and altimeter (or the tube may just have access to the cabin air pressure in the case of cheaper or lighter installations). This means that the inside of the diaphragm has the same pressure as the static pressure of the air surrounding the airplane. Opening into the otherwise sealed instrument case is a capillary tube, which also is connected to the static system of the airplane.

Figure 2-7 is a schematic diagram of a typical VSI. As an example, suppose the airplane 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.

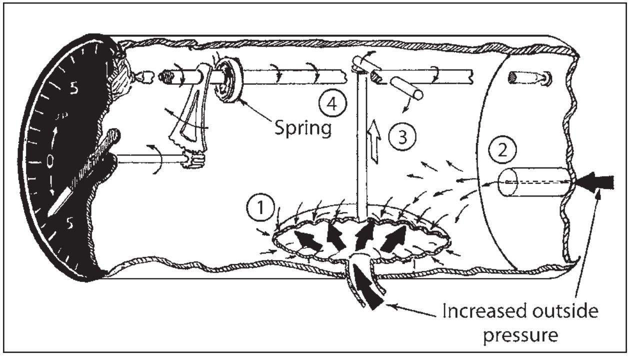


Figure 2-7. Vertical speed indicator and how it reacts to a descent.

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 (1). However, because of the small size of the capillary tube, the pressure in the instrument case does not change at the same rate (2). In a glide or dive, the diaphragm expands; the amount of expansion depends on the difference between the pressures. Since the diaphragm is mechanically linked to a hand (3), the appropriate rate of descent in hundreds (or thousands) of feet per minute is read on the instrument face (4).

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.

In a climb or dive the pressure in the case is always “behind” the diaphragm pressure in this instrument, thus a certain amount of lag results. The instrument will still indicate a vertical speed for 6–9 seconds after the plane has been leveled off. That’s why the VSI is not used to maintain altitude. On days when the air is bumpy, this lag is particularly noticeable. The VSI 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 sensitive altimeter is used to maintain a constant altitude, although the VSI can show the trend away from a desired altitude—if you realize that the lag is present. On the other hand, the VSI will also give a slight early indication of the direction of the altitude change before it is detectable on the altimeter, but it takes time to establish an accurate rate.

The pointer should read zero while the airplane is on the ground, and any deviation from this can be corrected by turning the adjustment screw on the instrument. You may also use the deviation (say, *plus* 100 feet) as the zero point. A 500-fpm climb would be performed at an indication of 600 fpm; a 500-fpm descent would call for the needle to be at a 400-fpm down-indication. It’s better, though, to have the instrument set properly.

There is an IVSI (instantaneous vertical speed indicator) in some airplanes that does not have lag and is very accurate even in bumpy air. It contains a piston-cylinder arrangement whereby the airplane’s vertical acceleration is immediately noted. The pistons are balanced by their own weights and springs. When a change in vertical speed is effected, the pistons are displaced and an immediate change of pressure in the cylinders is created. This pressure is transmitted to the diaphragm, producing an almost instantaneous change in indication. After the acceleration-induced pressure fades, the pistons are no longer displaced, and the diaphragm and capillary tube act as on the old type of indicator (as long as there is no acceleration). The actions of the acceleration elements and the diaphragm-capillary system overlap for smooth action.

It’s possible to fly this type of instrument as accurately as an altimeter, but its price is understandably higher than that of the standard vertical speed indicator.

The Pitot-Static System

The three instruments just discussed must have a dependable source of static (outside) air pressure in order to operate accurately. Figure 2-8 shows a schematic diagram of the pitot-static system and the instruments.

The static system shown in Figure 2-8 uses a Y-type vent system to decrease static errors in yaw. The locations of the static vents are carefully chosen to obtain the most accurate static (outside) pressure. The usual location is on each side of the fuselage between the wing and the stabilizer. (You’ve seen the signs, “Keep this vent clean.”) This is usually the most accurate system of those used.

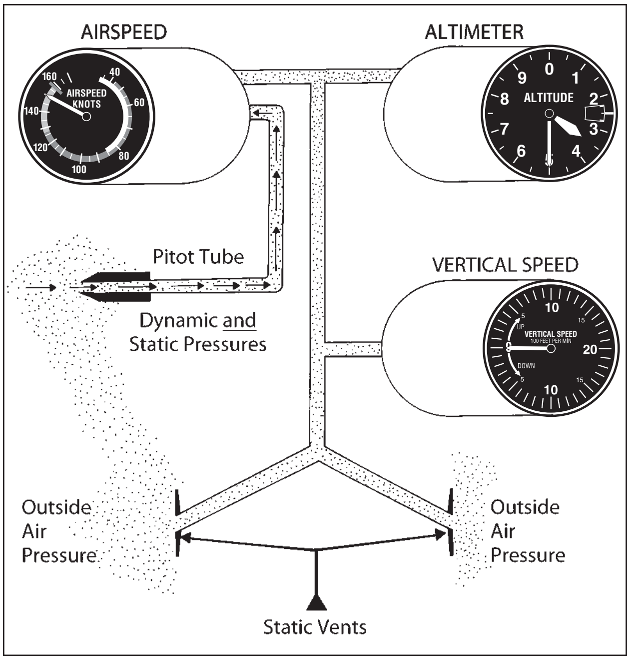


Figure 2-8. Pitot-static system using flush type Y static vents in the fuselage.

Another pitot-static system is shown in Figure 2-9. The static vent is located in the pitot-static tube.

The system shown in Figure 2-9 is not usually as accurate as the Y system, and in addition, the static opening at this location may be more susceptible to icing over if the airplane does *not* have pitot heat. (An airplane that expects to fly in icing had better have pitot heat!) This could mean loss of *all three* of the pitot-static instruments—not just the airspeed, as would be the case of the pitot tube Y vent system. (You'd still have static pressure to the airspeed indicator in the Y vent system but no impact pressure, so it would be out of the running if the pitot tube iced over. This will be covered in more detail at the end of this section.)

The instruments in older light trainers get the static pressure from the cabin. Because of the effect of the air passing by the cabin, a venturi effect may result, and the static pressure will be lower than the actual outside pressure, which would mean a slightly high airspeed and altimeter indication. Once the airspeed is stabilized, the VSI will not be affected because it is a "rate" instrument and would measure *change* of pressure as mentioned earlier.

14 CFR Part 23 (Airworthiness Standards for Normal, Utility, Aerobatic and Commuter Category Airplanes certificated prior to September 2017) notes that the static air vent system must be such that the opening and closing of windows, airflow variation, and moisture or other foreign matter do not seriously affect its accuracy.

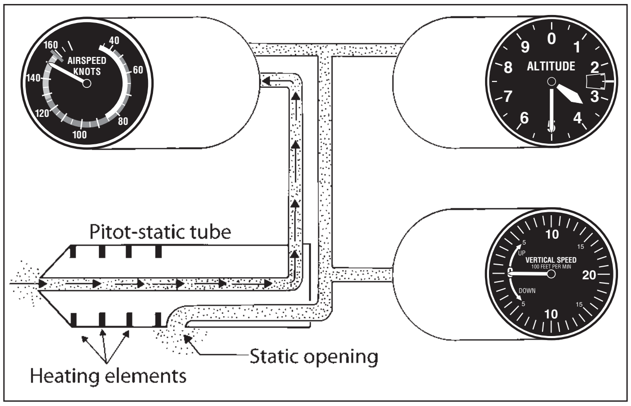


Figure 2-9. System with static opening in the pitot-static tube.

Pitot-Static System Problems

Pitot system—The big problem you can expect to encounter as far as the *pitot* system is concerned is that of ice closing the pitot tube (pressure inlet). The airspeed will be the only instrument affected in this case. The application of pitot heat, if available, is the move to make. It is best, however, to apply pitot heat before you enter an area of suspected icing and leave it on until clear. However, the pitot heat is a great current drain, and under some abnormal conditions you may want to use it intermittently.

Here is a little more detail about a blocked pitot tube. If the pressure is trapped in the pitot tube by ice or other debris, the airspeed will tend to increase erroneously as the airplane climbs. The static pressure in the case will decrease as the outside pressure decreases with altitude while the static pressure in the diaphragm stays the same, resulting in the diaphragm expanding and showing an "increase" in airspeed. The pilot raises the nose to correct for this (instead of also monitoring the attitude indicator), and there have been cases of stalls occurring in this situation. If the ram inlet is blocked and the water drainhole on the bottom of the pitot tube is not, the pitot tube pressure may escape and the airspeed will go to zero.

Static system—The more complex airplanes have an alternate static source that can be used if the primary system should get stopped up. This normally consists of a selector that the pilot turns to the "alternate" setting, which opens the system to cabin air (nonpressurized cabin). This then may have the same inaccuracies discussed earlier for the older system. (But it's a lot better than no static source at all.) Opening windows and vents and using the heater will affect the airspeed indicator readings on the alternate static source selections for many airplanes. With some airplanes the alternate static selection may cause the altimeter to read *lower* than normal at some indicated airspeeds, which would

Instrument Flight Manual Syllabus

A Flight Instructor's Checklist and Pilot's Guide to the Instrument Rating

Contents

Stage 1
Airplane Performance and Basic Instrument Flying

The biggest mistake made in instrument training is to move on too quickly to cross-country and approaches in the instrument syllabus, to the detriment of the trainee's progress. A too-early transition away from the basic instrument instruction will result in problems with the ATC flight portion of the training requiring a return to basics. The basics will be applied the rest of an instrument flying career in en route and approach work, and *should be covered thoroughly before moving on.*

Unit 1
Instrument Rating Requirements and Outline of the Course

Ground Instruction, 1.0 Hour

Review of 14 CFR §61.65. Briefly note the following as areas to be covered in the course.

_____ Instrument rating requirements. (See Chapter 1 of this book.)

_____ Ground training; aeronautical knowledge.

Aeronautical Information Manual.

  _____ ATC system and IFR operations.

  _____ IFR navigation and approaches.

  _____ Use of IFR en route and instrument approach procedure charts.

  _____ Weather reports and forecasts.

  _____ Safe and efficient operation of the aircraft under IFR rules.

  _____ Recognition of critical situations and windshear avoidance.

  _____ Aeronautical decision and judgment.

  _____ Crew resource management.

_____ Flight proficiency.

  _____ Preflight preparation (flight planning).

  _____ Preflight procedures. Checking the weather and NOTAMs.

  _____ Preflight check.

  _____ Air traffic control clearances and procedures.

  _____ Flight by reference to instruments.

  _____ Navigation systems.

  _____ Instrument approach procedures.
  _____ Emergency operation.
  _____ Postflight procedures.
_____ Aeronautical experience (minimums).
  _____ 50 hours of cross-country PIC, 10 hours in airplanes.
  _____ 40 hours of actual or simulated instrument time.
    _____ 15 hours of instrument flight training by a CFII.
    _____ 3 hours of instrument instruction within 60 days in preparation for the practical test.
  _____ Cross-country flight of 250 NM along airways or ATC-directed routing.
    _____ Instrument approach at each airport.
    _____ Three different kinds of approaches with the use of navigation systems.
_____ Discussion of the instrument and COMM/NAV equipment available in the training airplane(s) and/or flight simulator/flight training device to be used in the course.
_____ Papers required to be on board (A ROW).
_____ Discussion of the trainee's and instructor's schedules for the course.

Assigned Reading—Trainee: *IFM* (Chapters 1, 2, and 4). Instructor: *FIM* (Chapter 24).

Comments ____

____

____

Instructor ____

Date ____________________ Ground Instruction ____________________ Trainee Initials ____________________

Unit 2
Introduction to the Flight Instruments—The Four Fundamentals

Ground Instruction, 2.0 Hours

This will be an introduction to the flight instruments so that basic instrument flight instruction may start. More details on the operations and errors of these instruments in later briefings and flights. This period may be broken up into 2 sessions or more time may be used for ground instruction.

_____ Basic T instrument arrangement (or primary flight display layout, if applicable).
_____ Pitch instruments.
  _____ Attitude indicator.
  _____ Altimeter.
  _____ Airspeed.
  _____ Vertical speed indicator.

- ______ Bank instruments.
    - ______ Attitude indicator. Used for both pitch and bank indications; so it is the center of the Basic T scan.
    - ______ Heading indicator. Old and new types.
    - ______ Turn and slip. Usually electric but may be vacuum. Measures yaw only. Operates on the principle of precession.
    - ______ Turn coordinator. Usually electric-driven. Measures both roll and yaw; also, operates on principle of precession.
    - ______ Standard-rate turn.
    - ______ Magnetic compass. A short review of the compass as a heading instrument.
- ______ The instrument scan.
    - ______ Cross-check. The flight instruments must be checked continuously. (The attitude indicator should be included in every sweep of the other instruments.)
    - ______ Interpretation. Watch for *trends*; confirm with other instruments.
    - ______ Control. Control the airplane through instrument indications and/or trends.
    - ______ Use a slower scan in initial training and include all flight instruments.
    - ______ Engine instruments should be checked routinely (not every scan but every couple of minutes).
- ______ Working speeds of the airplane. The instructor should have these figured out in advance of the ground school session for the particular trainer being used. Use the procedure as indicated in *FIM* Figures 24-1 and 24-2 and accompanying description.
    - ______ Approach speed. This is the most important working speed. Gear down, flaps or partial flaps optional depending on the airplane. Probably no flaps used on the approach, but the speed should be chosen so that flaps may be extended after breaking out on final.
        - ______ Power setting (rpm, or manifold pressure and rpm as applicable) for a 500-fpm descent at the chosen configuration (clean or dirty).
    - ______ Holding. Clean configuration.
        - ______ Should be close to the approach airspeed, if not the same.
        - ______ Power setting. May vary slightly with weight and altitude.
        - ______ Max endurance is found at lowest altitude for reciprocating engines. (ATC will control altitude, however.)
    - ______ Max rate of climb speed. Vary (slightly) to match holding and/or approach speed.
- ______ Control and performance instruments.
    - ______ Control instruments control the airplane's performance.
        - ______ Attitude indicator.
        - ______ Manifold pressure and tachometer or tachometer alone (fixed-pitch props).
    - ______ Performance instruments. These indicate the actions of the airplane in straight and level, climbs, descents, and turns (the Four Fundamentals).
        - ______ Airspeed. Controlled by elevator or stabilator.
        - ______ Altimeter. Controlled by power; a trend indicator.