Airplane Instruments

1.1 COMPASS ERRORS

1. During taxi, you should check your compass to see that it is swinging freely and indicating known headings.

2. The difference between direction indicated by a magnetic compass not installed in an airplane and one installed in an airplane is called **compass deviation.**
    a. Magnetic fields produced by metals and electrical accessories in an airplane disturb the compass needle.

3. Magnetic compasses can be considered accurate only during straight-and-level flight at constant airspeed.
    a. When turning and accelerating/decelerating, the fluid level and compass card do not remain level, and magnetic force pulls "down" as well as toward the pole.
    b. These are known as the magnetic dip characteristics.

4. In the Northern Hemisphere, **acceleration/deceleration error** occurs when an airplane is on an easterly or westerly heading.
    a. A magnetic compass will indicate a turn toward the north during acceleration on an easterly or westerly heading.
    b. A magnetic compass will indicate a turn toward the south during deceleration on an easterly or westerly heading.
    c. Acceleration/deceleration error does not occur on a northerly or southerly heading.

5. In the Northern Hemisphere, **compass turning error** occurs when turning from a northerly or southerly heading.
    a. A magnetic compass will lag (and at the start of a turn indicate a turn in the opposite direction) when turning from a northerly heading.
        1) If turning to the east (right), the compass will initially indicate a turn to the west and then lag behind the actual heading until your airplane is headed east (at which point there is no error).
        2) If turning to the west (left), the compass will initially indicate a turn to the east and then lag behind the actual heading until your airplane is headed west (at which point there is no error).
    b. A magnetic compass will lead or precede the turn when turning from a southerly heading.
    c. Turning errors do not occur when turning from or through an easterly or westerly heading; Le., turning errors are minimized at 90^0 and 270^0 headings.

6. These magnetic dip errors diminish as acceleration/deceleration or turns are completed.

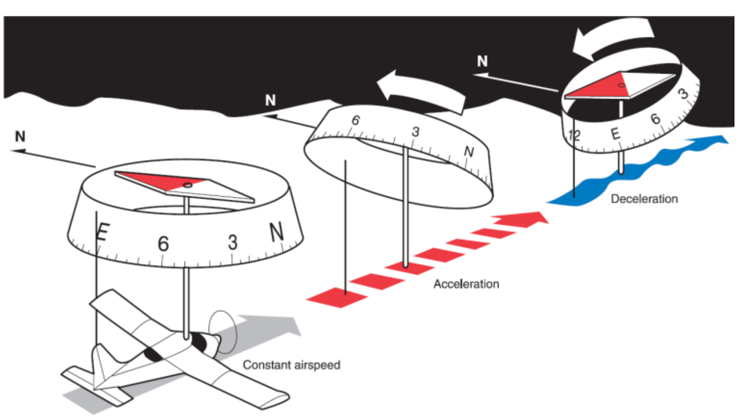

Figure 3-20. *The effects of acceleration error.*

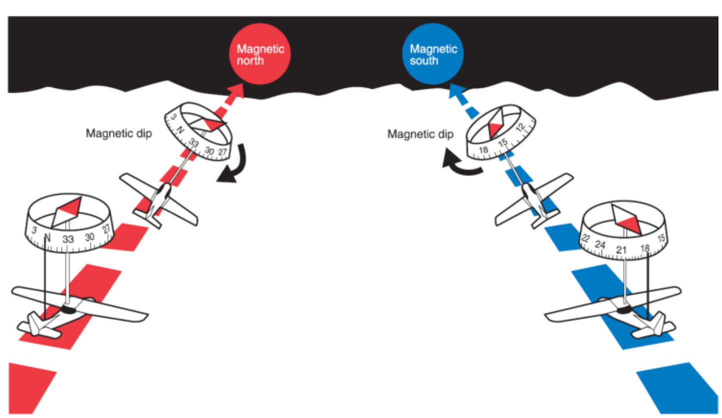

Figure 3-19. *Northerly turning error.*

1.2 PITOT -STATIC SYSTEM

1. When both the airspeed indicator pitot tube and the drain hole are blocked, the airspeed indicator acts as an altimeter.
   a. At a given altitude, airspeed changes would not change the indicated airspeed.
   b. During climbs, the indicated airspeed will increase.
   c. During descents, the indicated airspeed will decrease.
   d. These changes occur as a result of the differential between the pressure of the air locked in the pitot tube and the static air vent pressure.

2. If an alternate static source is vented inside an unpressurized airplane, the static pressure is usually lower than outside pressure due to the Venturi effect of the outside air flowing over the cockpit.
   a. The airspeed indicator will indicate a faster-than-actual airspeed.
   b. The vertical speed indicator (VSI) will momentarily show a climb.
   c. The altimeter will read higher-than-actual altitude.

3. If the pitot tube becomes clogged with ice during flight, only the airspeed indicator will be affected.
   a. The altimeter and vertical speed indicator depend upon the static air vents.
   b. If the static ports are iced over, the vertical speed indicator will not reflect climbs and descents because the change in air pressure cannot be detected by the VSI.

4. If the vertical speed indicator is not calibrated correctly (e.g., continually indicates a descent or climb), it can still be used for IFR flight by adjusting for the error when interpreting the indication.
   a. The VSI is not a required instrument for IFR flight. (Nonetheless, the FAA requires you to report the inability to climb/descend at least 500 fpm and the FAA Instrument Rating PTS requires constant rate climbs/descents.)

5. The Mach meter or Mach indicator shows the ratio of aircraft true airspeed to the speed of sound at flight altitude by means of the pressure differential between static and impact sources, with correction for temperature and altitude.

6. If the outside air temperature increases during a flight at constant power and a constant indicated altitude, true airspeed (TAS) and true altitude will increase.

1.3 ALTIMETER

1. The altimeter indicates the true altitude at the field elevation if the local altimeter setting is used in an accurate altimeter.
   a. Thus the altimeter indicates altitude in relation to the pressure level set in the barometric window.

2. Altimeters have three "hands" (like a clock's hour, minute, and second hands).

3. The three hands on the altimeter are generally arranged as follows:
   a. 10,000-ft. interval (thin needle with a flared triangular tip)
   b. 1,000-ft. interval (short, fat needle)
   c. 100-ft. interval (long, medium-thickness needle)

4. Altimeters are numbered 0 through 9.

5. To read an altimeter,
   a. First, determine whether the thin needle with the flared triangular tip rests between 0 and 1 (for 1-10,000 ft.), 1 and 2 (10,000-20,000 ft.), or 2 and 3 (20,000-30,000 ft.).
   b. Second, determine whether the shortest needle is between 0 and 1 (0-1,000 ft.), 1 and 2 (1,000-2,000), etc.
   c. Third, determine at which number the medium needle is pointing, e.g., 1 for 100 ft., 2 for 200 ft., etc.

6. Atmospheric pressure decreases about 1 in. Hg for every 1,000 ft. of altitude gained.

7. The altimeter setting dial allows adjustment for nonstandard pressure.
   a. A window in the face of the altimeter shows a- barometric scale that can be rotated.
   b. Rotating the altimeter setting dial changes the scale and the altimeter hands simultaneously in the same direction by 1,000 ft. per 1 in. Hg.
   c. For example, changing from 29.92 in. to 30.92 in. increases indicated altitude by 1,000 ft., or from 30.15 in. to 30.25 in. increases indicated altitude by 100 ft.

8. Prior to takeoff, the altimeter should be set to the current local altimeter setting.
   a. With the current altimeter setting, the indicated altitude of the airplane on the ground should be within 75 ft. of the actual elevation of the airport for acceptable accuracy.
   b. If the current local altimeter setting is not available, use the departure airport elevation.
   c. The local altimeter setting should be used by all pilots in a particular area, primarily to provide for better vertical separation of aircraft.
   d. During an IFR flight in Class E airspace below 18,000 ft. MSL, ATC will periodically provide the current altimeter setting.

9. The standard temperature and pressure at sea level are 15°C and 29.92 in. Hg.
   a. Pressure altitude is the indicated altitude when the altimeter setting is adjusted to 29.92 in. Hg, Le., the height above the standard datum plane.
   b. Pressure altitude is used in computations of density altitude, true altitude, and true airspeed.
   c. Pressure altitude will equal true altitude when standard atmospheric conditions exist.
   d. Pressure altitude and density altitude are the same at standard temperature.

10. The altimeter must be set to pressure altitude when flying at or above 18,000 ft. MSL.
    a. This setting guarantees vertical separation of airplanes above 18,000 ft. MSL.

11. Since altimeter readings are adjusted for changes in barometric pressure but not for temperature changes, an airplane will be at lower-than-indicated altitude when flying in colder-than-standard air.
    a. On warm days, you will be at a higher altitude (Le., true altitude) than your altimeter indicates.

12. When pressure lowers en route, your altimeter will register higher-than-actual altitude until you adjust the altimeter for the new altimeter setting.

1.4 GYROSCOPES

1. Listen to your electric gyroscopes for unusual noises after the battery is turned on but before the engine is started.
2. One of the characteristics of a gyro is that it is resistant to deflection of the spinning wheel, which is based on two of Newton's laws of motion.
   a. A body at rest will continue at rest and a body in motion will continue in motion in a straight line until acted upon by an outside force.
   b. Deflection of a moving body is proportional to the deflective force applied and inversely proportional to the body's weight and speed.

1.5 HEADING INDICATOR

1. The heading indicator (HI) should be set to the correct magnetic heading 5 min. after the engine is started.
   a. Prior to takeoff, check the heading indicator to determine that it continues to maintain the correct heading after taxi turns.

2. The remote indicating compass (RIG) combines the functions of the magnetic compass and the heading indicator. One component of the RIC is the slaving control and compensator unit, as shown in Fig. 143 on page 38.
   a. This unit contains a slaving meter needle which indicates the difference between the displayed heading and the actual magnetic heading.
      1) A right deflection (+) indicates a clockwise (right) error in the heading indicator compass card (Le., the correct magnetic heading is to the right of the indicated heading).
         a) Depressing the right (counterclockwise) heading drive button will move the heading indicator compass card to the left, thus increasing (+) the indicated heading toward the correct value (Le., from 180° to 190°).
      2) A left deflection (-) indicates a counterclockwise (left) error in the heading indicator compass card (Le., the correct magnetic heading is to the left of the indicated heading).
         a) Depressing the left (clockwise) heading drive button will move the heading indicator compass card to the right, thus decreasing (-) the indicated heading toward the correct value (Le., from 190° to 180°).
   b. To make corrections to the RIC, the system must be placed in the free gyro mode.
      1) After corrections are made, the system is returned to the slaved mode, which is the normal mode of operation.

1.6 **ATTITUDE INDICATOR**

1. Prior to IFR flight, you should check the horizon bar, which should be erect and stable within 5 min. of engine warm-up.
    a. The horizon bar should not tilt more than 5 ° when making taxi turns.
    b. Remember that you can adjust the position of the miniature airplane, but it is the horizon bar that moves to indicate attitude in flight.
        1) The horizon bar remains parallel to the horizon as the airplane's attitude changes.

2. **Precession errors** (both pitch and bank) on attitude indicators are greatest when rolling out of a 180° steep turn in either direction.
    a. As the airplane returns to straight-and-Ievel coordinated flight, the miniature aircraft will show a slight climb and a turn in the direction opposite to the turn just made.
        1) If you indicate straight-and-Ievel, you will be descending and turning in the direction of the turn just made.
    b. These precession errors during turns (including coordinated turns) are caused by centrifugal force acting on the pendulous vanes (erection mechanism in the attitude indicator). It results in the precession of the gyro toward the inside of the turn.

a.

3. Attitude indicators also reflect an error during skidding turns which precesses the gyro toward the inside of the turn.
    a. As the airplane returns to straight-and-Ievel coordinated flight, the miniature aircraft shows a turn in the direction opposite to the skid. Pitch indication is not affected.
4. Deceleration precession makes some attitude indicators incorrectly indicate a descent.
    a. Conversely, acceleration through precession may result in attitude indicators incorrectly indicating a climb.

1.7 TURN-AND-SLIP INDICATOR

1. Prior to engine start, the turn-and-slip indicator should indicate the needle centered, the tube full of fluid, and the ball approximately centered.
2. During taxi turns, the needle should deflect in the direction of the turn, and the ball should move freely opposite the turn due to centrifugal force.

1.8 TURN COORDINATOR (TC)

1. The miniature aircraft in the turn coordinator indicates rate of roll and rate of turn.
    a. When the bank is changing, the rate of roll along the longitudinal axis is indicated.
    b. When the bank is constant, the rate of turn along the vertical axis is indicated.
    c. Thus, the angle of bank is only indirectly indicated.

2. On taxi turns, the miniature aircraft indicates a turn in the direction of the taxiing turn, and the ball moves to the outside of the turn due to centrifugal force.

3. The miniature airplane will show a turn in a wings-level yaw or during a turn while taxiing.
    a. The TC indicates direction of roll along the longitudinal axis or yaw along the vertical axis and rate of turn.
    b. The TC does not give a direct indication of the banked attitude of the airplane.
    c. The TC does not display bank angle and rate of turn indirectly simultaneously.
        1) During a turn, the TC first shows the rate of bank indirectly and, once stabilized, the rate of turn.

4. For any given airspeed, a specific angle of bank is necessary to maintain a coordinated turn at a given rate. The faster the airspeed, the greater the angle of bank required to obtain a desired rate of turn.
    a. Standard-rate turn
        1) When the turn needle points to one of the small side marks, it indicates that the airplane is turning at a rate of 3° per second.

5. The inclinometer of the Te consists of a sealed, curved glass tube containing kerosene and a ball which is free to move inside the tube. The fluid provides a dampening action which ensures smooth and easy movement of the ball.
    a. A rate of 3° per second is considered a standard-rate turn, and completing 360° of turn requires 2 minute.
    b. The tube is curved so that the ball tends to seek the lowest point, which is the center of the tube during coordinated flight. Two reference markers aid in determining when the ball is in the center.
        1) During a coordinated turn, turning forces are balanced, causing the ball to remain centered in the tube.
        2) If turning forces are unbalanced, i.e., if improper rudder is used, the ball moves away from the center of the tube in the direction of the excessive force.
        3) In a skid, the rate of turn is too great for the angle of bank, and excessive centrifugal force moves the ball to the outside of the turn.
            a) To achieve coordinated flight from a skid, you should increase the bank angle, reduce the rate of turn by reducing the rudder force to center the ball, or use a combination of both.
        4) In a slip, the rate of turn is too slow for the angle of bank, and the lack of centrifugal force moves the ball to the inside of the turn.
            a) To achieve coordinated flight from a slip, you should decrease the bank angle, increase the rate of turn by applying rudder pressure to center the ball, or use a combination of both.
        5) Remember: In slips, you have used too little rudder (or opposite rudder). In skids, you have used too much rudder.
        6) Apply rudder pressure on the side that the ball is exposed; i.e., step on the ball.
        7) The ball then is a visual aid to determine coordinated use of the aileron and rudder control. During a turn, it indicates the quality of the turn, i.e., whether the airplane has the correct rate of turn for the angle of bank.

1.9 GLASS COCKPITS

1. "Glass cockpits," as they are commonly called, integrate many flight instruments with aircraft performance data on one or more screens to give flight status in a convenient, easy-to-read format.
    a. Glass cockpits and advanced avionics were designed to increase safety by enhancing situational awareness, presenting data in an easy-to-understand format, and performing many necessary tasks automatically.
    b. These systems are displayed in an electronic flight display (EFD).

2. A **primary flight display (PFD)** combines many flight instruments into a single presentation.
    a. These could include the altimeter, attitude indicator, vertical speed indicator, turn coordinator, HSI, and airspeed indicator.
    b. Other flight status information that may be displayed on a PFD could include distance and bearing to the next waypoint, ground track, outside air temperature, navigation instruments, and communication frequencies.
    c. Instrument sensor systems used to display information on a PFD are more sensitive and reliable than traditional gyroscopic instruments.
    d. A **multi-function display (MFD)** is often used as a backup PFD and is usually used to monitor engine and powerplant performance, fuel status, traffic, route selection, moving maps, approach charts, weather, and terrain avoidance.

3. As with flying conventional instruments, care is needed to maintain a correct instrument scan to correctly interpret instrument indications and avoid fixation.

4. All human activity involving technical devices entails some element of risk. Knowledge, experience, and flight requirements tilt the odds in favor of safe and successful flights. The advanced avionics aircraft offers many new capabilities and simplifies the basic flying tasks, but only if the pilot is properly trained and all the equipment is working properly.

5. While they have many benefits, much more initial and recurrent training is needed to acquire and retain the knowledge and skills necessary to accomplish a flight safely by means of glass cockpits.
    a. Pilots flying with advanced avionics or glass cockpits must continually learn their system's functions, capabilities, and limitations.
    b. With failure a possibility of any given system or display, a pilot must be able to perform manually any task being accomplished automatically.
    c. All aircraft equipped with electric flight instruments must also contain a minimal set of backup conventional instruments, usually consisting of an attitude indicator, airspeed indicator, and altimeter.
    d. Safety can be hampered or compromised if a pilot is not aware of what data is being presented or if it is used as a substitute for required preflight planning.

6. Most of the aviation community believes automation has made flying safer, but there is a fear that pilots fail to see that automation is a double-edged sword.
    a. Pilots need to understand the advantages of automation while being aware of its limitations. Experience has shown that automated systems can make some errors more evident while sometimes hiding other errors or making them less obvious.
    b. Humans are characteristically poor monitors of automated systems. When passively monitoring an automated system for faults, abnormalities, or other infrequent events, humans perform poorly. The more reliable the system is, the worse the human performance becomes.
    c. It is a paradox of automation that technologically advanced avionics can both increase and decrease pilot awareness.

7. Pilots should not become complacent or be lulled into a false sense of security simply because they have advanced avionics. Judgment and aeronautical decision-making serve as the bridge between technology and safety. Any flight you make involves almost infinite combinations of pilot skill, experience, condition, and proficiency; aircraft equipment and performance; environmental conditions; and external influences. Both individually and in combination, these factors can compress the safety buffer provided by your baseline personal minimums.