exposed to the air flowing past the airframe. As aircraft became more sophisticated, the venturi was replaced with an engine-driven vacuum pump, which is still in use today. Some aircraft use a pressure system rather than vacuum, but they essentially operate the same way.

The vacuum pump draws air from the gyro case, causing a partial pressure as illustrated in Figure 2-15. The opposite side of the gyro case has an air inlet that allows cabin air, after passing through one or more filters, to enter the case through a small jet nozzle shown in Figure 2-16. The jet directs the airflow toward the gyro's rim, where there are buckets called vanes that catch it and cause the gyro to spin like a water wheel. The optimum speed varies from 8,000 to 18,000 RPM, depending on the type of gyro and who manufactured it, and is controlled by the vacuum pressure setting. Since the reliability of the instrument depends on the gyro spinning at the prescribed speed, it is important that the vacuum be set correctly. In the electric-driven gyro, the rotating mass of the gyro is typically the rotor of the motor itself forming a neat, compact package. AC-driven systems operate at speeds as high as 24,000 RPM.

Precession

What makes the gyroscope useful in flying is the fact that a rotating gyro resists any force trying to alter its spin axis, a phenomenon known in physics as "rigidity in space." However, the spin axis will move somewhat, but because of the rotation it will move 90 degrees to the applied force in the direction of rotation. This phenomenon is illustrated in Figure 2-17. In the gyroscopic heading indicator, for instance, this antiproductive force causes the heading to drift slightly. Even in straight-and-level flight, there will always be some precession due to bearing friction, but excessive precession indicates an incorrectly operating and unreliable instrument.

Gyro System Preflight

It is important to allow sufficient time for gyro instruments to spin up to the correct RPM before relying on their accuracy. For air-driven instruments, that means at least five minutes; electric driven only require about three minutes. This is especially important during cold weather operations, when lubricant and contamination within the instrument can form a sludge that may significantly resist spinning.

The attitude indicator should be monitored during taxi. It should not display more than five degrees of change in pitch or bank unless you are taxiing on very hilly terrain. There was a time when instructors taught students to make an abrupt stop while taxiing to cause the airplane to sharply pitch down. During this maneuver the pilot was supposed to watch the attitude indicator and see if the pitch changed accordingly. Such a procedure should be avoided, as any hard braking is bad for the aircraft and may cause significant bearing damage to the gyros.

The miniature airplane on the attitude indicator is adjustable vertically, allowing the pilot to calibrate it as a reference for straight-and-level flight; leave it alone when you are not flying. The previous position will probably serve as a good guide for the next flight, at least until after you level off, when you may recalibrate it. Since airspeed, load, and ambient