followed an inoperative attitude indicator down. Always use a cross-check to assure proper instrument operation, including VSI, altimeter, airspeed, and a gyro instrument of a different power source. Believe what the majority of the instruments are telling you. If one instrument disagrees, it is probably wrong. Every few scans should include a check of the vacuum (or pressure) gauge and ammeter. Ideal operating vacuum gauge readings are depicted in Table 2-1.

Prior to entering actual IFR conditions, observe the gyro instruments carefully to assure correct operation. Monitor the vacuum gauge and ammeter. The time to discover problems is before you are forced to compensate for them.

Tumble limits on older heading indicators are 55–60 degrees of roll and pitch, but the newer horizontal card indicators are good to 80–85 degrees. Heading indicators do have gimbaling error on some headings, during banked turns. Typically there is a 2-degree error at 20 degrees of bank, 4-degree error at 30 degrees of bank and 10 degrees error at 45 degrees of bank. Gimbal error disappears upon return to level flight.

Older attitude indicators have tumble limits between 100–110 degrees of bank and 60–70 degrees of pitch, while the newer electric 3" horizons typically have 360 degrees of roll and 85 degrees of pitch up or down.

A case of tumbling gyros is bad news; it may cause significant damage to the gyro and in instrument conditions can be disastrous for the pilot. Be prepared for possible gyro failure or accidental tumbling. Your best insurance policy is to maintain partial panel proficiency and remember that the faithful, old turn and slip indicator is your most reliable gyro: it won't drift or tumble!

MAGNETIC COMPASS

While there have been many improvements over the years, the modern aircraft compass bears a striking resemblance to its earlier counterpart; certainly the fundamentals have not changed. Most science students have studied compass theory by floating a cork in a pan of water and placing a magnetized iron sliver or needle on top of it. Because the water has no static friction, the cork turns in response to the pull of the earth's magnetic field on the north-seeking pole of the needle. Water does have sufficient friction, however, to prevent the needle from overshooting. The cork also assures that the needle floats horizontally—a potentially significant problem the closer to the north or south pole the compass gets. This simple experiment, or variations of it, guided navigators at sea for centuries.

Table 2-1

Instrument	Minimum	Desired	Maximum
Attitude indicator	3.5	4.0	5.0
Heading indicator	3.5	4.0	5.0
Turn indicator	1.8	1.9	3.2