Directional gyro is not the complicated instrument you may think it is, but 'DG' does require proper care and an understanding of how it works for best results. Here are some facts about the gyro family every pilot should know

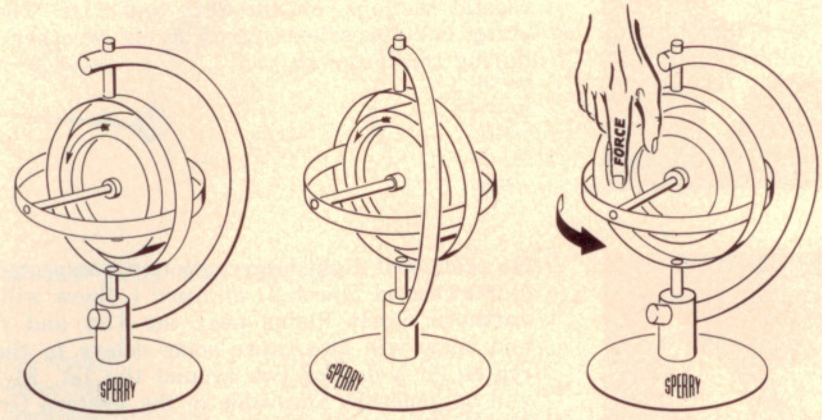

FIGURE 1 Two models at left illustrate "rigidity" of spinning gyro wheel. Note that when you turn the base on which the assembly is resting, it does not affect the direction in which gyro points. Model at right shows the principle of "precession." Gyro swings away from original heading (precesses) when acted upon by an outside force. In this case, a force pressing downward at a point on the inner gimbal causes gyro to move horizontally, as indicated by arrow. Gyro behavior is such that it always moves at right angles to direction in which force is applied

FIGURE 2

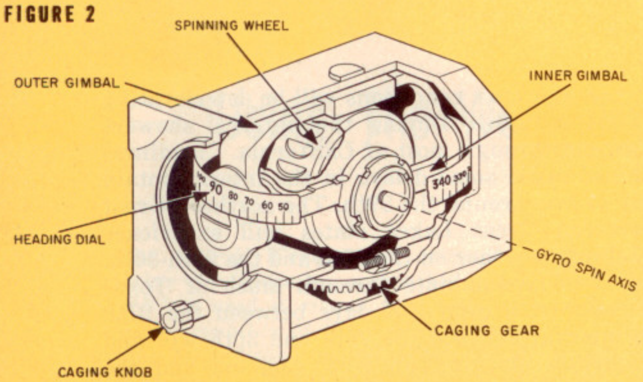

FIGURE 4

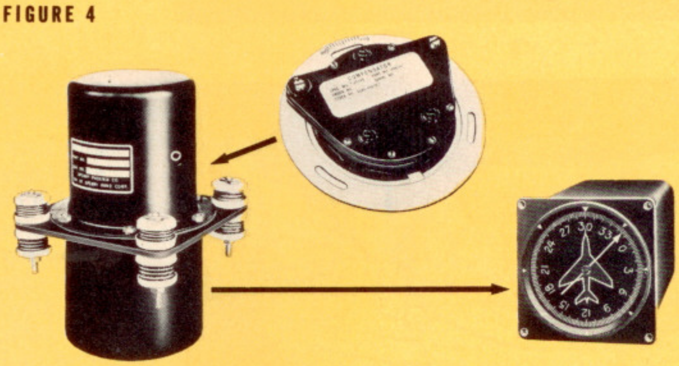

FIGURE 3

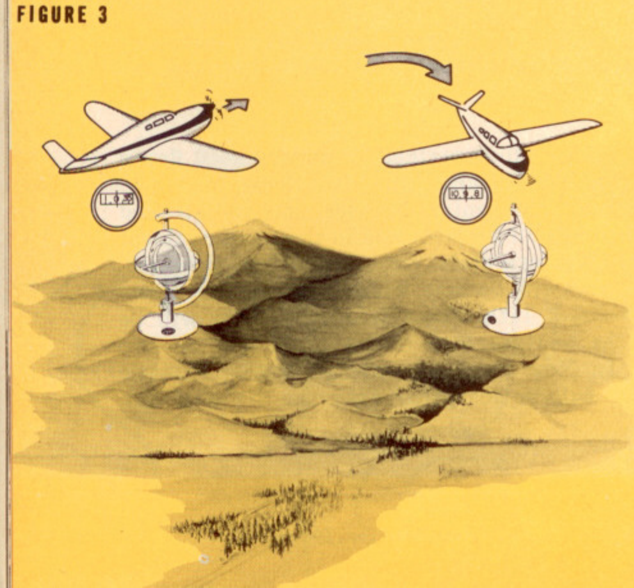

FIGURE 2 Cutaway view of surplus air-driven directional gyro shows principal details of construction. Note that heading dial is fixed to gyro spin axis through gimbal structure so that the dial remains stationary as the outer case (and the airplane itself) turns around the dial

FIGURE 3 Here is what happens in the directional gyro as the aircraft changes heading—90° in this case. Note that heading of aircraft and the outer frame of the model gyro are the same. Gyro remains pointed in the same direction as the aircraft (frame) turns freely. Extent of the turn is indicated inside the aircraft by changed readings on the dial

FIGURE 4 New Sperry Gyrosyn® Compass, developed especially for light aircraft, provides a directional gyro "slaved" to the earth's magnetic field. Small flux valve (center) detects magnetic north and sends "slaving" signal to electric gyro (left) to keep gyro properly aligned and eliminate need for resetting. Exact magnetic heading is shown on indicator (right) by nose of miniature aircraft. Optional pointer on face of indicator gives magnetic bearing to radio station tuned on aircraft's receiver. Sperry will market new system soon if demand from general aviation is judged sufficient

The Art Of Precise Direction

EDITOR'S NOTE: James Dohogne is an authority on gyro systems for airline, military and general aviation, and an active light aircraft pilot. He is responsible for development engineering of directional gyros and gyro horizons at Sperry Phoenix Company, the aeronautical division of Sperry Rand Corporation. He won his permanent flight instructor rating in 1961 and now gives weekend instruction at Deer Valley Airport near Phoenix, "just to keep current and for the fun of it."

New aircraft, hotter power plants, greater range, more payload. All have been getting prime attention in the current general aviation boom. And if he is willing to scratch below the surface a bit, a pilot easily can find a hundred additional topical items to keep hangar conversations lively.

Usually taken for granted and rarely part of a "serious" flying discussion these days are the gyro instruments which have done so much to make the boom possible. Indeed, many a VFR pilot has a problem in just trying to name the three basic gyro instruments: the directional gyro (DG), attitude gyro and rate-of-turn indicator. Still fewer pilots can tell you anything about gyro capabilities and weaknesses, to say nothing of the care and feeding of these instruments. It's easy to believe there is some form of witchcraft associated with gyroscopics, which, as we shall see, is really not the case at all.

The term "gyro" actually is a very general one, and examples can be found almost anywhere. A gyro is any mass (weight) that rotates. The earth is a large gyro which rotates about its axis once every 24 hours. The wheels of a bicycle are gyros and, if they didn't exhibit a couple of odd characteristics called "precession" and "rigidity," it would be virtually impossible to keep the bike upright or to turn it.

An aircraft gyro consists of a spinning wheel (called the rotor) which is supported within several rings (called gimbals). The number of these gimbals varies with the intended use of the gyro. For example, the turn indicator has a gyro suspended in one gimbal while the attitude gyro and directional gyro have two such gimbal rings.

Two simple but very important properties make the gyro a natural for use as a flight instrument: rigidity and precession. Rigidity is the stubbornness the gyro exhibits in trying to keep its spin axis always pointed in the same direction. Precession refers to the way the gyro's spin axis moves when pushed or acted upon by any external force. This movement, oddly but accurately, is always at right angles to the direction in which it is pushed. (See Figure 1.)

To avoid confusion, let's first look at the DG and temporarily ignore the other two types.

Various DG's have many faces and methods of presenting their information, but the basic purpose in each case is to provide a stable heading reference for navigation and precise maneuvering. The DG must be teamed with the aircraft's magnetic compass, using the magnetic compass initially to align the DG to the proper magnetic heading, after which the DG becomes the prime navigational reference. In this manner, the familiar bobbing and weaving of the magnetic compass is traded for a stable, easily readable heading indication—essential to modern IFR flying and a great boon to VFR navigation.

The gyro shown in Figure 2 is a simplified version of the widely used air-driven DG which had its hey-day in military use during World War II. Because it is a proven instrument and was available in large quantities on the surplus market after the war, it still is widely used in general aviation.

The air-driven DG consists essentially of a spinning wheel which is supported on low-friction ball bearings within two gimbal rings. This entire assembly rests within the instrument case on another set of ball bearings. The gimbals are arranged in such a way that the gyro has 55° of freedom in pitch and roll—before striking mechanical stops—and complete 360° freedom in heading.

It is possible to "tumble" the gyro if aircraft bank or climb angles exceed 55°. Tumbling is indicated by a rapid rotation of the heading card and is quickly remedied by resetting the gyro in a way we shall describe shortly.

Bearing in mind that the DG has no north-seeking ability, it obviously must be set to agree with the magnetic compass at the beginning of each flight. After this initial setting, the gyro should be checked with the magnetic compass and reset every 15 to 20 minutes—always during straight-and-level flight. These periodic corrections compensate for the tendency of the DG to drift slowly away from its original alignment.

In order to set the gyro to the desired heading, the knob on the front of the case is depressed and turned. This action meshes two gears and actuates a lever which holds the gimbals while the entire gyro assembly is turned to any desired heading. The action of holding the

(Continued on page 74)

by JAMES DOHOGNE • *AOPA 215966*

Drawings and photos by Sperry Phoenix Company

Precise Direction

(Continued from page 39)

gimbals fixed, by depressing the knob, is called "caging." It is done chiefly to prevent the gyro from tumbling while setting a heading. The gyro also should be kept caged during maneuvers in which pitch or roll operating limits of 55° are likely to be exceeded. Pitching or rolling beyond these limits causes high loads on the ball bearings which support the gimbals and can result in damage, particularly if maneuvers become violent.

The gyro rotor operates at a speed between 12,000 and 16,000 r.p.m. and is powered much like a water wheel. An engine-driven vacuum pump, or outside venturi, is used to create a partial vacuum inside the DG case. The vacuum causes air to rush inward through a filter at the rear of the case. The air is ducted across the gyro wheel which has "buckets" around its circumference, causing the rotor to spin. Air leaves the instrument through another hole in the rear of the case.

The so-called "leveling" action in a DG is a bit more difficult to describe, but still is a relatively simple procedure. Leveling is quite important because the gyro must be kept spinning in a horizontal plane if acceptable accuracy is to be maintained. The effects of friction in the ball bearings supporting the gyro, however, cause it to try to move away from a level position. A certain quantity of the "exhaust" air from the rotor is therefore ducted rather cleverly so that this tendency to leave the horizontal plane is continuously overcome by an equal and opposite action. This leveling system will not operate properly, however, unless the vacuum in the instrument is kept between 3.5 and five inches of mercury. Optimum operating vacuum is four inches of mercury, and this is the chief reason why small vacuum indicators appear on many instrument panels.

The way in which the DG indicates aircraft heading is shown in Figure 3, and is very easy to understand. The pilot simply reads the heading on the dial, which indicates the direction in which the gyro itself is pointing. As the airplane turns, a change in the dial reading results from the fact that the gyro case, which is attached to the airplane, is rotated *around the spinning gyro*. Taking a little time to make a mental picture of this action is very helpful to many pilots who say the DG indications seem to move in reverse.

Errors in a directional gyro may be divided rather generally into those encountered in level flight and those in turning maneuvers.

The primary error in straight-and-level flight is a slight deviation from a set heading, a deviation which increases with time. This error is called drift, and it is the chief reason a DG should be reset every 15 or 20 minutes to agree with the magnetic compass. Setting the gyro is at best an approximate process, especially in rough air, because the magnetic compass refuses to stand still.

Drift is caused primarily by gimbal unbalance and friction in the ball bearings. These are corrected—or compensated—at the time of overhaul, so that normal drift in a properly-functioning DG is limited to ± 12° an hour. Performance can deteriorate because of bearing wear, contamination from poor air filtering, or reduced wheel speed from a low vacuum. To check a DG's drift rate, carefully set the gyro to agree with the magnetic compass and fly straight and level for exactly 15 minutes. Note the difference at the end of this time between the DG and magnetic compass inidications, and multiply by four. This latter figure will give you degrees-per-hour of gyro drift.

DG errors during turns are of two basic types: those resulting from leveling action in the gyro and those produced by the gimbal supports (gimbal error).

Leveling error in turns will average to zero for a 360° turn and generally will be at a maximum following a turn of 180°. This error will be small (about 1° maximum for a standard-rate turn) so don't worry about it.

Gimbal error, in engineering parlance, results from the fact that the output axis of the gyro during a turn is inclined to the vertical by the bank angle of the airplane. This sounds much worse than it is. A simple analogy is a universal joint linkage in which the drawing shaft is at an angle to the output shaft. There is no gimbal error on headings of 0°, 90°, 180° and 270°, regardless of the bank angle, and error is at a maximum (as much as 13° in a steep-bank turn) on intermediate headings. The important thing to remember about gimbal error is that it exists only when the aircraft is banked or pitched and *as soon as the aircraft returns to*

(Continued on page 78)

Directional Gyro
OPERATING CHECKLIST

1. For best accuracy, maintain an up-to-date deviation card at 45° intervals for your magnetic compass. This is important for setting the DG and periodically checking its performance in flight.
2. Set your DG to agree with magnetic compass at beginning of each flight, but not before gyro wheel has had a chance to build up speed. This takes about four minutes. In setting DG, depress knob on front of case and turn as necessary. **Be sure to pull knob out again after setting.**
3. Check DG heading against magnetic compass indication every 15 minutes during level flight. Reset if necessary. Maximum adjustment in 15 minutes should be 3° to 4° if gyro is operating properly.
4. Set the DG only after centering the turn indicator and waiting for magnetic compass oscillations to settle.
5. Allow for gimbal error in steep turns. Don't judge rate of turn by rate of change indicated by gyro.
6. Cage your DG when maneuvers exceeding 55° in pitch or roll are anticipated.
7. Have your DG checked during annual or 100-hour inspections. Overhaul as advised by an FAA approved gyro repair shop.

(Continued from page 74)

approximately level flight the DG will indicate the correct heading. In short, it is a characteristic of much more interest to the engineer than to the pilot. The worst effect of gimbal error in everyday flying is a slight heading inaccuracy while rolling into and out of turns, causing mild overshooting or undershooting. Gentle entries and recoveries from turns will greatly reduce even this small error.

Giving full weight to its many virtues, the air-driven DG still must be classed as the product of pre-World War II technology. Every aspect of gyroscopics has been improved greatly since air-driven gyros were introduced, but probably the most important single change has been the development of electrical gyros. The requirement for electrical DG's originated in the military for reasons of reliability and because there are altitude limitations on the use of the suction pump.

While there are many advantages to electrical instruments, most gyro authorities agree that the following two are the most significant:

1. Longer time between overhauls and much better operational reliability because of improved cleanliness. (No need to circulate air through the instrument.)

2. Much better performance (lower drift) with the larger and faster gyro wheel, improved gimbal bearing suspension and leveling system.

Because a conventional DG must be reset constantly (because of drift) to the readings of the magnetic compass, the next logical development in improving heading information was to handle this job automatically and continuously. This is called "slaving" the gyro to a magnetic reference. The first system to incorporate this feature was the Sperry C-1 Gyrosyn® Compass introduced in 1944. Since then, many developments have resulted in improved performance and reliability. Today, magnetically slaved systems are in almost universal use by airlines and the military, as well as many executive operators.

Consider that one airline is now averaging 6,300 hours between overhauls of its compass systems—six to 10 times the between-overhaul life of top-performing air gyros in airline service—and it is easy to see why this change has taken place.

For general aviation, slaved systems of the past have been too expensive, heavy and have required too much electrical power. In recent months, however, Sperry has developed a magnetically slaved system tailored specifically for light aircraft, requiring only one amp. from a 24-volt electrical system or 2 amps. from a 12-volt system. Early production is foreseen if surveys show an adequate market for this new equipment. In order to illustrate the basic principles of slaved compass operation, it is described in Figure 4.

A "flux valve" is used to detect the direction of the earth's magnetic field, and this information is transmitted electrically to the gyro and amplifier assembly. (Both of these units are mounted remotely in the aircraft.) If the gyro heading does not agree with the flux valve heading, an electrical signal is developed in the slaving amplifier which is used to drive a "motor" which precesses the gyro in the proper direction to cancel the error. This process is automatic and continuous, and once the system is initially aligned, the heading indicated to the pilot remains within 2° of the correct magnetic heading—giving many times the navigational accuracy of the separate magnetic compass and DG.

The remote gyro permits use of a variety of heading instruments (rotating pointer, rotating card, radio-magnetic indicator), and provides space for autopilot signal sources. A small static inverter is used to convert aircraft DC power to the necessary AC voltages.

Whichever gyro you use—whether air driven or electrical—it is a precision instrument and requires careful treatment. With proper installation and intelligent operation, it will do a splendid job, accurately and reliably. But remember that its care and feeding is a specialized task—a job for nothing less than an FAA approved gyro repair shop. END

(Continued from page 77)