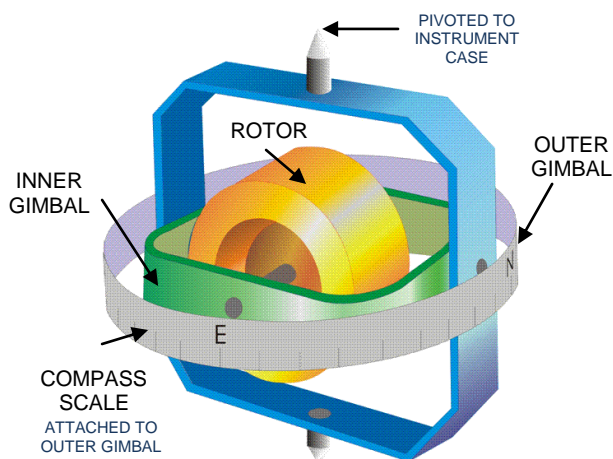


DIRECTION INDICATOR

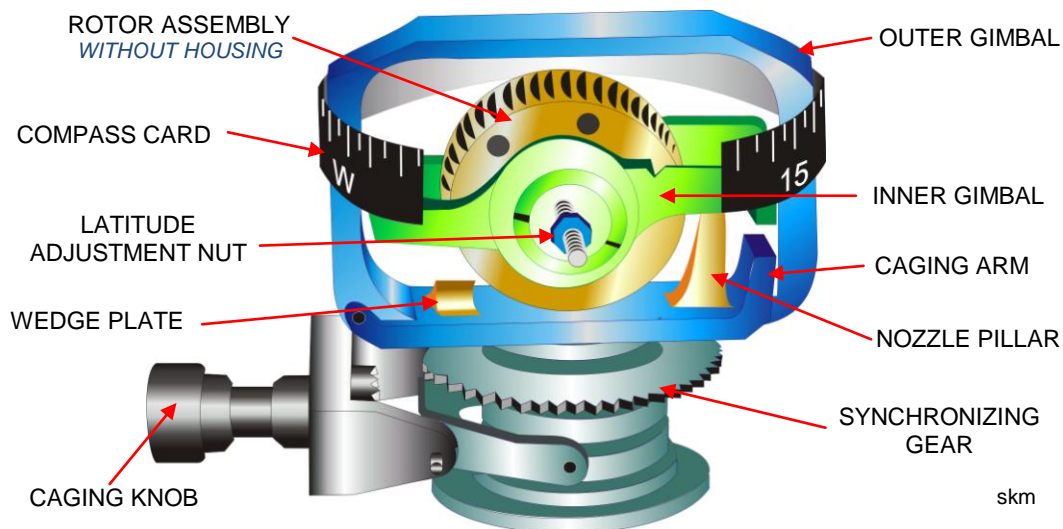
Heading of helicopter is indicated by a Directional Indicator (DI) also known as Directional Gyro (DG) utilizing the property of rigidity of gyro. A DI provides a stable reference in azimuth for steering precise heading and executing accurate turns. Unlike direct reading magnetic compass it does not suffer from errors like acceleration, turning and liquid swirl. It is not north seeking as there is no magnetic element and is also required to be synchronized at regular intervals with desired reference to correct for real and apparent gyro drifts. The DI is not a replacement but complementary to magnetic compass.

CONSTRUCTION and OPERATING PRINCIPLE. A gyro with horizontal spin axis is mounted in an inner gimbal and rotates in vertical plane – as in the figure here. Horizontal inner gimbal is pivoted to a vertical outer gimbal along an axis, perpendicular to spin axis. Thus, inner gimbal is free to move about a horizontal axis right angles to the spin axis. Outer gimbal in turn is pivoted to instrument case along the vertical axis and therefore has complete freedom to move about this axis. The figure here shows the major components of an air-driven suction type of DI.



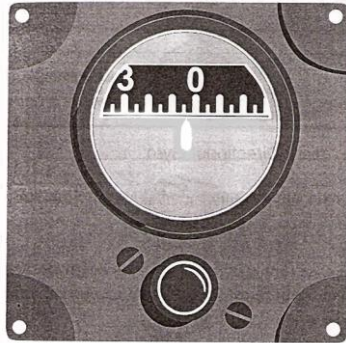
Horizontal inner gimbal is pivoted to a vertical outer gimbal along an axis, perpendicular to spin axis. Thus, inner gimbal is free to move about a horizontal axis right angles to the spin axis. Outer gimbal in turn is pivoted to instrument case along the vertical axis and therefore has complete freedom to move about this axis. The figure here shows the major components of an air-driven suction type of DI.

In vertical display type of instruments (old ones) a ribbon like compass card is fixed to the outer gimbal as shown in the figure below. With outer gimbal and attached card being kept aligned



with reference datum as magnetic north by the gyro, the heading and any changes to it are read against a lubber line. Face of such an instrument is shown in the

figure on the left below. Modern indicators use a rotating card instead in a similar manner, marked 360° and moving against the index showing the heading as in a



VERTICAL DISPLAY DI (OLD)

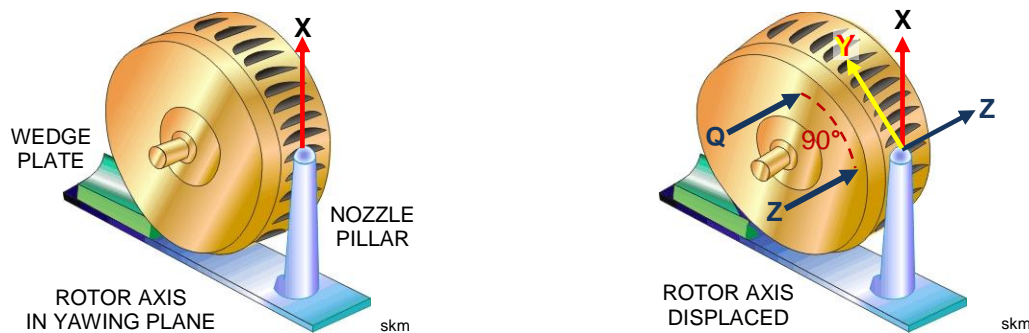


HORIZONTAL DISPLAY DI (MODERN)

horizontal display, as on the right side in figure. A gear drive between the outer gimbal and the azimuth card achieves this rotation when change in heading takes place.

In air driven gyro, rotor spins as action of jet of air impinging on indentations on rim of the rotor, working as a tiny turbine. The air jet may be result of replacement air to suction created by vacuum or supply of compressed air by a pump. In both cases the air is passed through a fine filter. In electrically driven DIs, the rotor may be turned by electrical power as in the case of a motor.

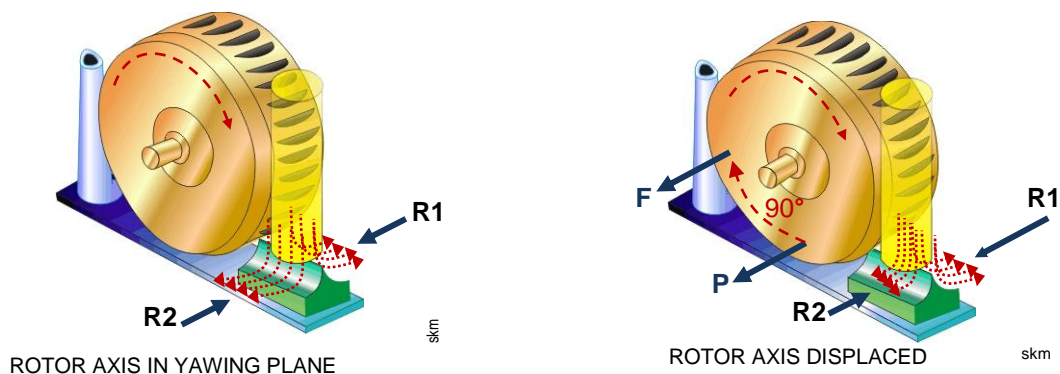
CONTROL SYSTEM. As explained above, in suction type DI, the gyro rotor is driven by jet of air, applied from a nozzle pillar fixed to the outer gimbal. The air jets besides spinning the rotor also tie its axis in the yawing plane of helicopter. Full force of the jets 'X' is used to drive the rotor when rotor's axis lies in yawing plane and is at 90° to axis of the outer gimbal. When helicopter banks, rotor axis remains



fixed in space due to rigidity of the gyro and now is no longer in the yawing plane of helicopter. Force 'X' driving the rotor acts at an angle to the rotational plane because outer gimbal axis and rotor axis are no longer at right angles. Instead of 'X', its component 'Y' in the plane of rotation is now spinning the rotor, and other component 'Z' is acting at right angles to plane of rotation. 'Z' will have a processing effect at a point 90° moved in direction of rotation. The result would be application of force 'Q' to bring the rotor axis back to the yawing plane. Thus, any tilt of the rotor axis would be corrected by appropriate torque created by air jet and

indentations on the rotor rim. It should be noted that in case rotor axis happens to be aligned with the longitudinal axis of helicopter due to a particular heading, bank change only with no yaw for turn, will not displace the rotor axis out of yawing plane.

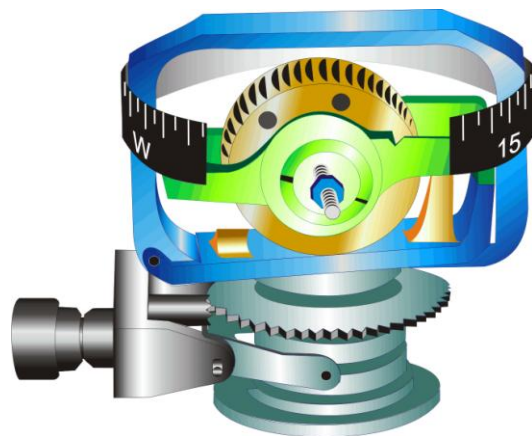
Second part of the control system works with exhaust air. The jet of air while spinning the rotor flows along it in the metal case and is exhausted on the other side on a wedge plate fixed on the outer gimbal. When the gyro axis is horizontal,



the exhaust jet is divided in two equal halves by the wedge plate, producing equal reactions R1 and R2. As a result rotor axis remains in the yawing plane as shown in the left figure above. Components of exhaust air become unbalanced when rotor axis is displaced from the yawing plane. The resultant acts as a torque on outer gimbal and processes the rotor and inner gimbal. Thus, an imbalance force 'P' acts as 'F' at point removed through 90° in direction of rotation to bring the rotor axis back to the yawing plane. This is indicated in the figure above on the right side. The wedge provides fine adjustment while course alignment is done by the jet.

The control system in electrically driven DIs utilizes two levelling switches connected to respective torque motors which keep the spin axis always horizontal by applying suitable torque. The system is similar to one used in Attitude Indicator and detailed explanation is available in the notes on Attitude Indicator.

CAGING DEVICE. On the front of the instrument an adjustment knob is provided, which when pushed in, moves a caging arm, locking the inner gimbal at right angles to the outer gimbal. This action locks the rotor axis in the yawing plane and the gyro is unaffected by any torque during synchronisation process. It also engages a bevel gear with outer gimbal. Rotating the adjustment knob rotates the outer gimbal and attached compass card. Figure here shows the DI in caged position, as the caging knob is pressed in and synchronizing gear is engaged locking both gimbals. The figure here should be compared with the one



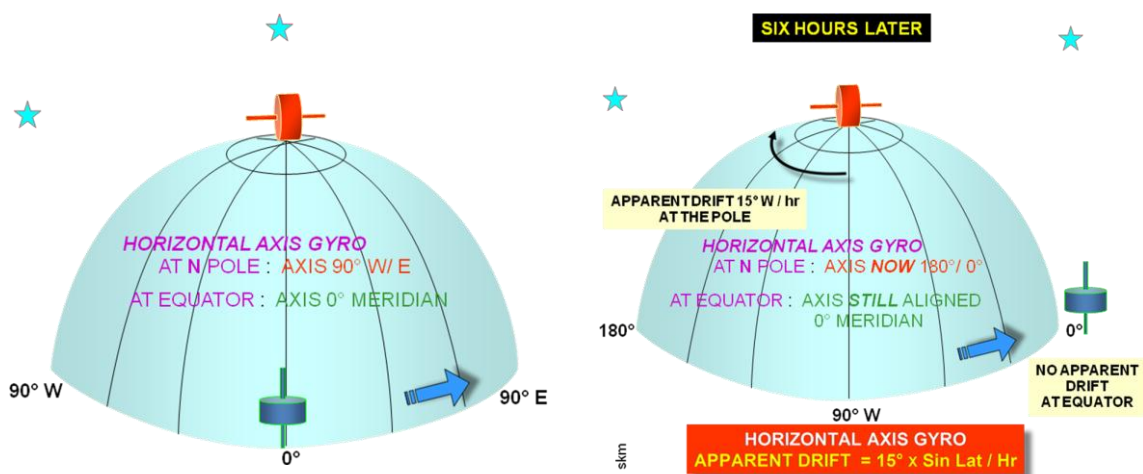
presented earlier for better comprehension. The scale reading can thus be synchronized with required heading, usually the magnetic compass reading. This adjustment in flight should only be carried out while flying straight and level. Toppling and possible damage to the instrument may be prevented by caging the gyro before any violent or other manoeuvres beyond the specified roll and pitch limits. In case the gyro has toppled, with caging it may be quickly re-erected and re-synchronized.

ERRORS of DI

Unlike magnetic compass the gyro of DI cannot remain aligned to a set reference for a long period due to several causes. The significant ones are discussed here.

Gimballing Error. DI depends on geometry of the gimbals that is required to be maintained mutually 90° for correct indications of direction. A pitch or bank about lateral or longitudinal axis of helicopter being about gyro's freedom axes does not affect its rigidity. But a simultaneous pitch and bank manoeuvre on any heading, where changes in attitude take place along any axis other than freedom axis of gyro, results in precession of outer gimbal and indication of false change in heading. Also, if helicopter banks in level flight on a heading that is 45° removed from gyro axis direction, the outer gimbal itself must move to maintain the systems rigidity, giving an erroneous indication of change in its direction. This error is known as Gimballing error and is small during moderate changes in attitude and disappears once level flight is resumed.

Apparent Drift due to Earth's Rotation. Consider a horizontal axis gyro placed at true North Pole, where all directions are South, with its axis aligned to 90° W/ E meridian as shown in the figure on the left (red gyro). After six hours the axis of gyro will get aligned with 180° / 0° meridian, as in figure on the right. This is



due to the fact that gyro keeps its direction with reference to a point in space and

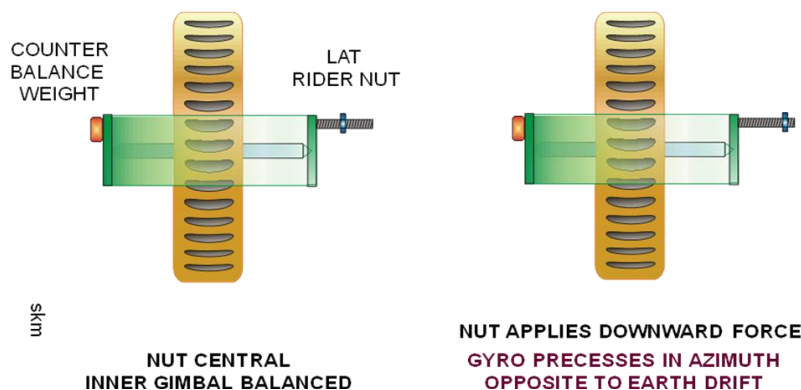
the Earth is rotating at 15°/ hour towards east. Therefore, to an earth bound observer the gyro would appear to be drifting at rate of 15°/ hour westwards.

Now consider, the gyro (blue) placed at the equator and its horizontal axis aligned with Prime meridian that is true north direction. It would not be affected by Earth's rotation, at all because both the space reference and earth reference are in same direction and remain to be so throughout. Therefore, at Equator apparent drift due to Earth's rotation will be zero. It may be concluded the apparent drift is a function of sine of latitude and rate of Earth's rotation. It is expressed as;

$$\text{Apparent Drift (degrees/ hour)} = 15 \times \text{Sin latitude}$$

The effect is westwards drift in Northern hemisphere resulting in decrease of heading indication. In Southern hemisphere it is opposite – eastwards or increase in indication of heading with passage of time.

Drift Compensation. Apparent drift due to Earth's rotation for any particular latitude on DI can be corrected by applying an equal drift on the gyro in opposite direction. It is done by providing a threaded spindle with a small nut, called *latitude nut* that is attached to the inner gimbal. With the nut in the central position the inner gimbal is perfectly balanced, because it is manufactured with slight imbalance. Screwing in or out the rider nut will vary the downward force applied to the gyro rotor. The



latitude nut is adjusted in the laboratory to precess the gyro at some rate as the earth at required latitude but in opposite direction. Thus, effect of apparent drift about any operational latitude can be minimized. It should be noted that if flying in opposite hemisphere than one for which the compensation has been made, the total drift effect will be more than that in case of an uncompensated gyro.

Random Wander. Other than apparent drift discussed above the gyro would suffer from 'real wonder' due to manufacturing imperfections, wear and tear, and imbalance in pivot bearings. In Direction Indicators, rigidity is of a high order and random drift (or wander) is rather low. Air driven gyros spinning at 10,000 to 20,000 rpm are quoted to have drift rate of about 16°/hr to 12°/hr respectively. Electrically driven gyros have only few degrees/ hr of real drift rate.

Unstable Rotor Speed. Precession rate of a gyro depends upon rotor rpm, which is not precisely controlled in suction type of DIs. In such cases latitude nut

compensation does not remain accurate. At slower speed than the designed one resulting in lower rigidity of the gyro and latitude nut providing a pre-set constant and higher precession rate, over correction of apparent drift would take place. Exceeding the design figure of rpm is unlikely in air-driven type of DIs.

Pilots Serviceability Checks.

- Check power source; suction gauge reading within range/ warning flag not visible.
- Align DI with magnetic compass before taxing. Check it remains aligned and indicates turns correctly during taxing.
- In flight check with right turn DI readings increase and vice versa in level flight after it has stabilized in case of having toppled earlier.
- DG must be aligned with magnetic compass only in level flight.

SUMMARY

DIRECTION INDICATOR provides stable reference in azimuth for steering precise heading and executing accurate turns utilizing property of rigidity of gyro. Complementary to magnetic compass.

Construction. Horizontal axis gyro mounted in an inner gimbal which is pivoted to a vertical outer gimbal. Outer gimbal pivoted to instrument case and free to move about vertical axis. Compass card fixed to the outer gimbal.

Control System. A nozzle pillar at the air jet's input and a wedge plate fixed at exhaust end on the outer gimbal keep the gyro axis in horizontal plane. While gyro axis is displaced, a component of air jet acts as torque on the gyro to precess its axis back to horizontal. At the same time, an imbalance in two halves of exhaust air across the wedge plate causes similar precessing action.

Caging Device. Locks the rotor axis in the yawing plane and the gyro is unaffected by any torque during synchronisation process. Rotating the adjustment knob rotates the outer gimbal and attached compass card for synchronization of heading.

ERRORS

Gimballing. Caused due geometry of the gimbals. Simultaneous pitch and bank manoeuvre on any heading, results in precession of outer gimbal and indication of false change in heading. Also there, if bank/ pitch on a heading 45° from gyro axis direction.

Apparent Drift due to Earth's Rotation. Westwards drift in Northern hemisphere resulting in decrease of heading indication. Opposite effect in Southern hemisphere. Effect of apparent drift about any operational latitude can be minimized by latitude nut adjustment.

Random Wander. 'Real wonder' caused due to manufacturing imperfections, wear and tear, and imbalance in pivot bearings. Air driven gyros error is about $16^\circ/\text{hr}$ to $12^\circ/\text{hr}$. Electrically driven gyros have only few degrees/ hr of real drift rate.

Unstable Rotor Speed. At slower speed than the designed one lowers rigidity of the gyro and latitude nut providing a pre-set constant and higher precession rate, causes over correction of apparent drift.

Pilot's Checks

- Check power/ pressure and warning flag.
- Align before taxing and check operation while moving on ground.
- In-flight align with compass only in level attitude.