Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

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Gyroscopic Instrument Reliability

1. Effectivity

All aircraft equipped with spinning-mass gyroscopic attitude and navigation instruments, particularly air-driven gyro instruments.

2. Purpose

Provide advice to enhance the reliability of instruments which utilize a spinning mass gyroscope such as the artificial horizon (AH) (vertical spin axis) gyro, the directional gyro (DG) and the rate of turn indicator gyro - often combined with a slip/skid indicator and called the “Turn and Bank”.

3. Background

Spinning mass gyro instruments are precision pieces of equipment widely used for primary aircraft attitude and directional reference by the pilot and by an autopilot during instrument flight. Indication errors and gyro failures may result in loss of control of the aircraft.

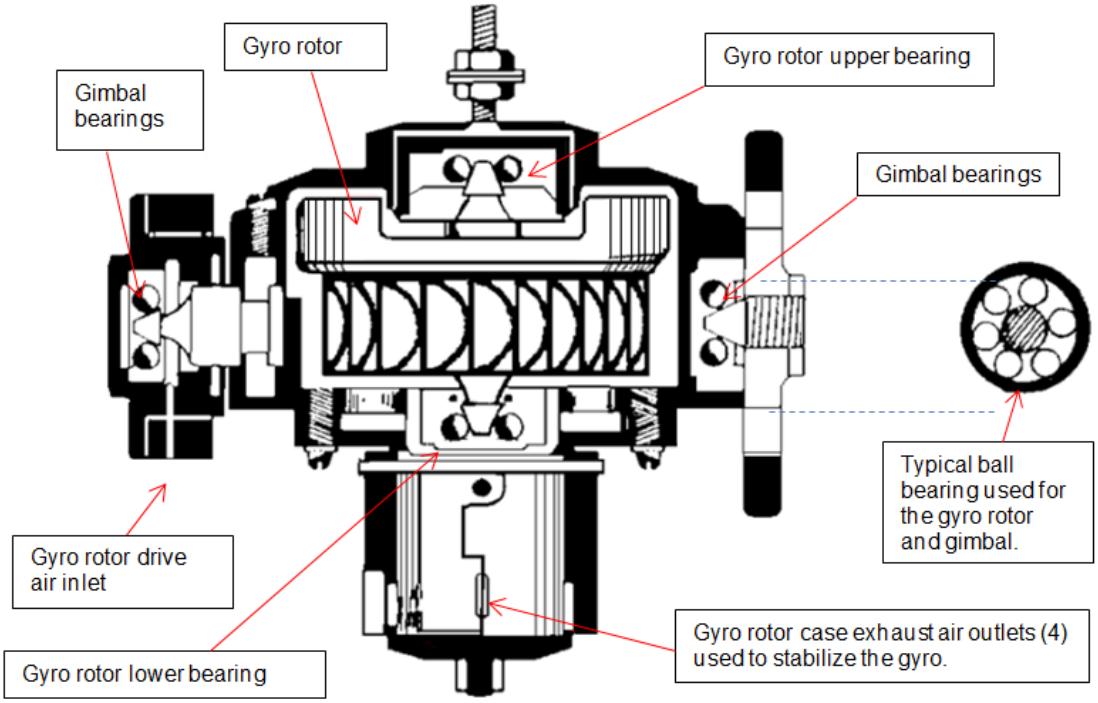

Figure 1 - A typical classic air-driven vertical spin axis gyroscope (artificial horizon) design, showing typical bearing arrangement and low bearing contact area which makes the bearings susceptible to any shock damage. Note how the bearings are exposed to the same air used to drive the gyro

The most common failure mode for a gyro indicator is bearing failure, which can be caused by any one or a combination of the following factors:

- Normal wear due to time in service.
- Adverse wear due to the instrument ingesting dirty air via a missing or defective gyro /or vacuum relief valve filter in a vacuum system.
- Contamination by debris from a failed vacuum pump in a pressure system, where the filter was inadequate and/or the system was not purged correctly following pump failure.
- Impact damage (brinelling) to the gyro rotor and gimbal bearings.

Inadequate vacuum or pressure system air filtration causes rapid bearing wear. Shock or impact damage can be inflicted during aircraft ground handling, or by rough or improper handling at any time during installation, storage and shipping

3.1 Gyro Handling – aircraft on the ground

Many light aircraft are equipped with air-driven gyros for the artificial horizon (AH) and directional gyro (DG) instruments. When the engine is shut down, the engine-driven vacuum/pressure pump which powers these gyro instruments also stops operating. The gyro not only loses motive power but the source of the gyro stabilizing forces (via precession) as well.

This leaves the gyros in a high energy state (spinning at around 20,000 RPM) without the gentle gyro stabilizing forces that the vacuum/pressure source provided. If the gyros are still spinning during the typical sharp 90° turn and push-back into the hangar (a violent manoeuvre which is well outside the capability of any gyro stabilizing device) an uncaged gyro - even halfway through the spin-down period - is very liable to ‘topple’ (spill) and have more than enough energy to slam the mechanism against the gyro gimbal limit stops, causing shock damage to the gyro and gimbal bearings and cause the gyro to enter a condition known as ‘gimbal lock’, where the AH horizon reference bar goes rapidly and repetitively to extreme attitude indications and the DG heading display spins.

Even with the more recent gyro gimbal designs in electrically powered gyros, the gyro can enter a gimbal lock condition, where the gyro ‘tumbles’ and forces the gimbals to spin at high speed (being energised by the gyro) exceeding the gimbal bearing design limits and damaging the bearings. Damaged gyro and gimbal bearings will result in false indications and unanticipated instrument failure.

Gyro instruments which have had the power removed should be left for the amount of time specified in the aircraft data - usually about 15 to 20 minutes, to allow spin-down and stop before the ground-handling the aircraft. Use this period to listen to the gyro instruments as they wind down. If the instrument is vibrating (lightly touch the instrument glass) or if growling or grinding noises are heard, and/or if an air-driven instrument stops relatively quickly, have the instrument checked by appropriately qualified maintenance personnel. Some electrically driven gyro instruments do slow down quickly, but do so smoothly and quietly when serviceable.

The pilot should report all gyro instrument system anomalies, such as excessive directional gyro (DG) heading drift or poor artificial horizon bar pitch/roll alignment to the maintenance facility, since such pre-indicators of failure are often only detected in flight.

3.2 Gyro Handling - in the cockpit

CAUTION!

GYRO - HANDLE LIKE EGGS

The gyro and supporting frames or gimbals run on very delicate bearings which are able to absorb the normal range of aircraft flight manoeuvres and landing loads when correctly installed and operating. However, gyro instruments will soon give increasingly erroneous readings after having suffered jarring or shocks resulting from heavy landings or rough handling during installation or bumps and shocks inflicted while being moved from the store to the aircraft or during shipping. Gyro instrument failure rate is often directly related to rough or improper handling.

Gyro instruments cannot withstand the shock of being dropped, jarred, or struck by pieces of equipment. Shocks cause the ball bearings to indent the race and brinell (indent) the bearings. Dropping or handling a typical gyro instrument so that it impacts a hard surface from about 7mm. (¼" inch approx.) can result in something like a 14G shock to the gyro which can brinell the bearings and result in vibration, accelerated bearing wear, loss of gyro RPM and excessive heading drift in directional gyros. While some directional and vertical gyro designs may incorporate vibration isolation absorbers, the rate gyro (turn and bank) may not, making it particularly sensitive to even light handling shocks.

Do not place gyros directly on any hard surface. Place a generous foam pad between any hard surface and the gyro instrument. Handle like eggs!

Gyros should never be removed from the instrument panel while they are running or spinning down. A gyro normally operates at between 20,000 to 24,000 rpm and can take 10 or more minutes to run down. Some gyros, if removed while running and tilted more than 20° during removal, may develop 'gimbal lock' and damage the bearings.

During removal from the instrument panel, treat a malfunctioning gyro instrument with the same care and respect due to a new or serviceable one. It is easy to think of a gyro that has become unserviceable as one destined for the scrap pile, but that is usually not true. However, poor handling will turn a relatively minor fault in a gyro to a major fault that can result in the unit being scrapped. It is therefore very important that proper handling procedures be employed during removal, and during every phase of gyro instrument maintenance.

3.3 Gyro Handling and Shipping Guidelines

To prevent damage to a gyro while being handled during maintenance, the instrument should be transported to and from the aircraft in the original shipping container. If this is impractical, the gyro should be hand-carried carefully in its normal installed and operating attitude. Keep the original shipping containers that the gyro instrument has been received in for transportation and future re-shipment. Gyro instrument overhaul and repair facilities report that gyro instruments have been received with extensive bearing damage in addition to the reported defect as a result of improper shipping packaging.

3.4 Gyro Instrument Panel Installation

Panel Wedges

Most helicopters and some aeroplanes require a special “wedge” to be installed between each gyro instrument case and the instrument panel to ensure the gyro spin axis and gyro frames or gimbals will be properly aligned to the aircraft flight attitude and will operate in its properly erected position during flight. This is particularly true of the vertical gyro or artificial horizon.

Helicopters typically cruise a few degrees nose-down and some aeroplanes have a forward-sloping instrument panel relative to the longitudinal axis. While some artificial horizon instruments will have a small moveable aeroplane symbol to allow the pilot to adjust for minor longitudinal trim angles, gyro instruments will provide highly erroneous indications if installed without the specified shim or wedge of the correct value between the panel and the gyro case.

Panel Mounts

Some aircraft provide a separate gyro instrument panel which is rubber shock mounted. During any gyro instrument installation, inspect the rubber panel mounts for signs of permanent set, ageing cracks and separation. Replace defective rubber mounts in sets. In more than one instance, the rubber isolating panel mounts have failed and allowed the gyro instrument panel to drop down, immediately rendering the instruments ineffective and restricting elevator ‘up’ movement, resulting in loss of control.

3.5 Gyro Overhaul

Gyro instruments should be overhauled and tested in accordance with the manufacturer’s data. It is acceptable to use out of print OEM procedures providing the gyro instrument is at the same amendment status as the last OEM approved publication and no other organisation has taken over authorisation to manufacture the gyro instrument.

If the data is no longer obtainable, applicable guidance material and/or industry standards may be used. Alternatively, a CASA or subpart 21M authorised person with an appropriate aircraft flight instrument engineering speciality on their instrument of appointment may develop the data.

Alternative replacement components are acceptable providing the replacement part is an approved alternate.

3.6 Directional Gyro Heading Drift / Latitude Compensation

Due to the rotation of the earth, and the orientation of the directional gyro (DG) spin axis, all directional reference gyros will want to drift from the heading set by the pilot during flight. The rate of apparent drift will vary according to the latitude at which the aircraft operates. Some directional gyro designs will have automatic latitude compensation when linked (slaved) electronically in a magnetic compass system, and/or have a means to allow the pilot to apply latitude correction to compensate for gyro heading drift.

Basic directional gyros, however, require the pilot to 'cage' the gyro and manually re-set the heading every few minutes during flight. The frequency at which the gyro has to be re-set depends on factors such as gyro imbalance, bearing wear, internal gimbal friction and the accuracy of the internal compensation or latitude correction for the particular geographic location. The maximum gyro drift error is considered to be approximately 4° per 15 minutes. Drift compensation or latitude calibration for a basic DG is usually set at overhaul.

When sending a DG overseas for overhaul, be aware of the earth hemisphere to which the gyro is being sent and which earth hemisphere it is intended to be operating. Some gyro overhaul facilities based in the Northern hemisphere receiving a DG from Australia recognise that the gyro will be operating in the Southern hemisphere and will automatically provide "Southern Correction". Specifying "Southern Correction" on the Purchase Order for an overhaul of a DG intended for installation in an aircraft operating in Australia should ensure an acceptable latitude correction calibration is applied.

Acknowledgements: Gyro handling notes have been adapted from Sperry Technical Newsletter 23-3000-01

4. Recommendations

- Pilots should report all gyro defects detected during flight to maintenance personnel.
- Wait for gyro instruments to completely spin down before manoeuvring the aircraft on the ground or removing the instrument from the aircraft.
- Handle all gyro instruments "LIKE EGGS" at all times.
- Overhaul and test gyro instruments in accordance with paragraph 3.5 of this AWB.

5. Related CASA Gyro system AWBs

AWB 37-002 - Aircraft Gyro Instrument Vacuum / Pressure Systems – Functional Testing.

AWB 37-003 - Dry Vacuum Pumps.

6. Reporting

Report all gyro instrument defects to CASA via the Service Difficulty Reporting System, or via email to SDR@casa.gov.au.

7. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link email address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Standards Branch
Standards Division
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601