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AC-MIT-016-66

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TO: Mr. John E. Miller

FROM: Mr. W. J. Beaton

DATE: 12 August 1966

SUBJECT: SUMMARY OF SIGNIFICANT EVENTS UP TO TIME OF FAILURE OF IRIGS 4A-27, 6A-30, 5A-8, 5A-15, 5A-21

In order to provide some clue that might prove helpful in determining the cause of the subject gyro failures, the following assembly of information has been collected:

4A-27 - Removed from Y S/M axis of IMU #4, G&N 121 during retest at AC Milwaukee because of 30 meru shifts (decrease) in ADSRA and ADIA. This system had the Optics 28 VDC applied to the 800 cps line during systems test in the spacecraft at NAA. Resultant damage required that it be returned to Milwaukee for repair. It was noted, the last G&N gyro coefficient data taken at NAA showed a shift of about 25 meru (increase) in ADSRA. After repair of the IMU at Milwaukee it was retested and discovered that the Y gyro had experienced the above shifts.

6A-30 - This unit was removed from a system at MIT after having the ADIA term shift about 50 meru. This shift was noted after a gimbal runaway had occurred.

5A-8 - Located in X S/M axis of IMU #9. Experienced about 2½ earth rates shift in ADIA during spacecraft testing of G&N 12.

History of Events:

4-25-66 Went into S/C

7-6-66 Ran G&N Operational Check, everything okay.

7-8-66 Power glitch occurred while system was in Coarse Align. Apparently someone had pulled or tripped over a cord supplying prime power because S/C lights went out, the IMU gimbal dumped, and the ACE console lost sync. It took about 10 minutes to get power back on during which time the IMU was not downmoded.

7-9-66 Batteries supplying S/C power failed very fast. It was three to five minutes before they got house power. It is believed the ISS was in Coarse Align at the time. This power failure also caused loss of sync on the ACE console.

7-9-66 Power was lost again for five to ten seconds while the G&N was in Operate mode. It was noted during this period that the IMU 16X resolver readout on the ACE console was swinging from plus 70° to minus 70°, at a very fast rate. Since this meter can only read $\pm 70^{\circ}$ of gimbal angle the inference is the resolver was rotating at a high rate.

7-11-66 Performed G&N Operational Check and it indicated high gyro drift rates.

7-14-66 Repeated G&N Operation Check and got the same results.

7-15-66 Removed ISS from S/C.

7-19-66 ISS check in lab revealed three earth rate drift of X gyro. The IMU was returned to Milwaukee and the X gyro removed for analysis. Teardown findings were considerable debris, some metallic some separator material, and complete loss of bearing preload. The wheel bearing balls when measured were 130 u inches smaller in diameter than they were originally, yet they were matched within 7 u inches. Also noted in the findings was the presence of iron oxide.

5A-15 - This gyro had recently been installed in the Y position of IMU #2. It had been shipped to NAA from Milwaukee after replacement of the X and Y gyros. During early ISS tests at NAA it was noted the ADIA shifted about 1600 meru. Conversation with MIT/NAA did not disclose any unusual events, that could explain this sudden shift. Teardown analysis of this unit at Milwaukee revealed essentially the same conditions as were present on unit 5A-8.

5A-21 - This gyro was in the Y position of IMU #11. Upon receipt of this IMU at NAA from KSC an ISS performance test indicated a 40 meru shift in ADIA. During shipment from KSC this IMU had been dropped; the shock recorder indicated a 25g shock on the Y axis had been sustained.

Popular Failure Theories

It has been noted that all of the above gyros except 6A-30 were manufactured using ball separators from two manufacturer lots. Three of four other gyros having separators from these same lots have unstable performance history.

Separator Lot A-12

5A-8 Failed IMU #9.
4A-30 Failed in reliability test program - same conditions as 5A-8.
5A-18 Unassigned - retest data looks good.
5A-5 In G&N 109 - ADIA shifted about 40 meru-no further data.
5A-21 Removed from IMU #11 for ADIA shift of 40 meru.

Separator Lot A-11

5A-15 Failed in IMU #2.
4A-29 In IMU spare 2 data slightly jumpy.
4A-27 Removed from IMU #4 for ADIA and ADSRA shift.

Tests at AC have shown these separators bleed out lubricant at a faster rate than other separators. It is theorized this bleedout ultimately resulted in lubrication starvation which precipitated high temperatures due to friction, causing a chemical formation of iron oxide that acted as a lapping compound on the balls. The lapping of the balls took place over a relatively short period of running time and caused a loss of bearing preload. Additional testing of wheels with very little bearing lubricant has shown this effect does take place.

Another theory postulates that with the balls riding on a 10 u inch oil film it would require an angular input of only about seven radians per second to break through the oil film and get the same conditions as described above. During ISS testing with the GSE there is a Gimbal Dump Circuit which senses rates of the inner gimbal in excess of three to four radians per second and downmodes the system.

Because of response time it is possible the gimbal could see as high as five radians per second before being downmoded. However, this circuit is inhibited for 16 seconds when commanding Coarse Align and with the torque motors saturated the gimbals can be driven at about 10 radians per second. This could be quite severe on the gyros for large gimbal angles at turn on.

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