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EIGHTH PROGRESS REPORT

For Period 1 July 1968 to 1 January 1969

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STERILIZABLE WIDE ANGLE GAS BEARING GYRO FGG334S

California Institute of Technology
Jet Propulsion Laboratory
Contract No. 951529

HONEYWELL Aerospace Division

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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ABSTRACT

This document is the eighth Progress Report, covering the period 1 July 1968 to 1 January 1969, for the Wide Angle Gas Bearing Gyroscope FGG334S, submitted in accordance with Contract No. 951529. This report defines progress to date and technical problems encountered and solved.

CONTENTS

SECTION I
PROGRESS, PROBLEMS, AND FUTURE PLANS

PROGRESS

- Two gyros were shipped, bringing the total to three.
- The fourth gyro was built and has completed sterilization and shock testing.
- The gimbal assembly for the fifth gyro was completed.
- Minor revisions were made in the test program.

PROBLEMS

- A major delay in shipment of gyro No. 4 occurred as the result of a particle in the gimbal, which caused nonrepeatability of 4 deg/hr and necessitated a gimbal teardown.
- Another major delay occurred when rework intended to correct an end-to-end balance problem precipitated a crack near the header end of gimbal No. 5. As a result, a new gimbal cup was necessary.
- A processing problem developed in the coil cup and was corrected. Processing of the newer coil cups had resulted in insufficient insulation material between wires at a point where an S. G. secondary wire crossed a torquer wire near a torquer terminal.

FUTURE PLANS

- Completion of test program and shipment of gyro No. 4.
- Completion of gyro build test, including sterilization and shipment of unit No. 5.
- Submission of the Final Report.

SECTION II
DISCUSSION

GYRO PERFORMANCE

Significant test results from four to the five gyros to be built on this program are presented in Table 1. Although each unit shows some individual differences, performance has been quite consistent from unit to unit, and several conclusions may now be drawn about the overall performance of this design.

Torque stability has been comparable to gyros of like size, weight, and power. Cooldown stability of reaction torque, MU_{IA}, and MU_{SRA} has been very good, 0.1 deg/hr or better on all units. Spinmotor reaction torque (SMRT) remains the major contributor to drift instability, although it has been greatly reduced by the gimbal shield. A technical development on a Honeywell in-house program, the GG134M, has shown a promising "fix" which would be applicable to future GG334S gyros. When the first GG134M showed SMRT similar to the GG334S, the unit was rebuilt incorporating a hypernik ring to shield the H-ring. The SMRT in the rebuilt gyro was reduced by an order of magnitude.

The present torquer configuration has resulted in a torquer scale factor of 350 deg/hr/ma, with very little variation. Although this is lower than required by contract, it satisfies the thinking when the torquer was designed and the contract was written. At that time, the goal was a scale factor greater than 300 deg/hr/ma.

Another trend noted in the data is the tendency of the elastic restraint to exceed 0.06 deg/hr/mr. On unit B-1, a special test was run to determine the effect of an elastic restraint compensating capacitor. The results of this

Table 1. Acceptance Test Results

Parameter	B1	B2	B3	A4	Units
Gyro Transfer Function	10.22	8.88	------	9.66	volts/radians
Damping	2.96×10^5	2.53×10^5	2.70×10^5	2.44×10^5	dyne-cm-sec
Gimbal Freedom	+3.05 -3.10	-2.93 +3.15	+3.17 -3.42	+3.12 -2.97	deg
Operating Temperature	181.2	180.0	178.14	180.9	°F
Spinmotor					
Start Power	4.2	6.2	5.98	6.6	watts
Run Power	2.6	3.35	3.10	3.3	watts
Runup Time	26.0	16.1	17.6	14.4	seconds
Run Down Time	65.8	50.0	52.3	44.0	seconds
Pickoff					
Sensitivity	24.38	23.47	24.63	24.3	volts/radian
Null Voltage	1.28	------	2.5	3.4	mv
Torquer Scale Factor	362.23	340.5	350.01	349.58	deg/hr/ma
SMRD Output Signal	6.8	9.8	9.1	8.0	mv
Fixed Torque	+0.278	-0.098	-0.059	+0.209	deg/hr
MU_{IA}	-0.344	+0.075	-0.214	-0.214	deg/hr/g
MU_{SRA}	+0.096	-0.003	+0.254	+0.078	deg/hr/g
RMS Drift Stability	0.055	0.042	0.037	0.096	deg/hr
Drift Stability (Cooldown)					
Fixed Torque (Δ RMS)	0.078	0.080	0.033	0.10	deg/hr
MU_{IA} (Δ RMS)	0.019	0.045	0.037	0.086	deg/hr
MU_{SRA} (Δ RMS)	0.058	0.063	0.040	0.025	deg/hr
Random Drift					
OAV	0.002	0.009	0.001	0.007	deg/hr
IAV	0.007	0.007	0.003	0.004	deg/hr
Elastic Restraint	-0.596	-0.077	-0.070	-0.099	deg/hr/mr
Anisoelastic Coefficient					
100 Hz	+0.098	+0.115	+0.063	+0.11	$deg/hr/g^2$
500 Hz	+0.031	+0.022	+0.030	0.00	$deg/hr/g^2$
1000 Hz	-0.022	+0.004	0.00	0.00	$deg/hr/g^2$
2000 Hz	-0.150	+0.186	+0.223	-0.032	$deg/hr/g^2$

test are presented in Table 2. The 0.047 μf capacitor changed the signal generator sensitivity to 28.16 volts/radian and reduced the secondary output phase angle from +28 deg to +4 deg (leading).

The relatively high anisoelastic coefficient at 2000 Hz is the result of resonance which occurs at approximately 2300 Hz.

Table 2. Elastic Restraint Compensation, Special Test, Gyro S/N B

Compensating Capacitor	Elastic Restraint
0.060 μf	+0.050 deg/hr/mr
0.055 μf	+0.025 deg/hr/mr
0.050 μf	-0.030 deg/hr/mr
0.047 μf	-0.042 deg/hr/mr
0.045 μf	-0.055 deg/hr/mr
0.040 μf	-0.125 deg/hr/mr
uncompensated	-0.620 deg/hr/mr

Sterilization Testing

Gyro S/N A4 was subjected to the six, 72 hour, +275°F sterilization cycles required by the contract. The results are presented below in Tables 3 and 4 and in Figure 1. As expected from previous experience with the GG159E and the earlier sterilizable gyros, the first sterilization cycle caused the largest shifts. Spinmotor parameters, random drift, and stops were unaffected by sterilization temperatures. Other drift parameters may be summarized as follows:

Parameter	Design Goal (Each Cycle)	Test Results
Change in TSF	±4.0 deg/hr/ma	Max spread 2.4 deg/hr/ma
Change in RT	±0.08 deg/hr	0.249 deg/hr(Avg); 0.418 deg/hr(max.)
Change in MU_{IA}	±0.014 deg/hr/g	0.129 deg/hr/g(Avg); 0.162 deg/hr/g(max.)
Change in MU_{SRA}	±0.14 deg/hr/g	0.152 deg/hr/g (Avg); 0.348 deg/hr/g(max.)*
Change in Elastic Restraint	±0.15 deg/hr/mr	0.006 deg/hr/mr total

* Excluding the first point as not representative. Including the first point, the values would be 0.338 (avg); 1.288 (max).

Shock and Vibration Testing

Gyro S/N 4 was also subjected to shock and vibration testing. The results are presented in Tables 3 and 4, and in Figure 1.

Spinmotor parameters, stops, and random drift were unaffected by the environmental exposures. Other drift parameters tested are summarized below:

Parameter	Design Goal (Shock/Vibration)	Test Results Shock	Test Results Vibration
Change in Torquer Scale Factor	±4.0 deg/hr/ma	0.6 deg/hr/ma	0.16 deg/hr/ma
Change in RT	±0.04 deg/hr	0.147 deg/hr	0.210 deg/hr
Change in MU_{IA}	±0.15 deg/hr/g	2.57 deg/hr/g	2.09 deg/hr/g
Change in MU_{SRA}	±0.15 deg/hr/g	0.327 deg/hr/g	0.158 deg/hr/g

Table 3. Environmental Test Results, S/N B4

	Reaction Torque	MV_{IA}	MU_{SRA}	OAV Drift	IAV Drift	Torquer Scale Factor	+ Stop	- Stop	Start Power	Run Power	Run Up Time	Run Down Time
	(deg/hr)	(deg/hr/g)	(deg/hr/g)	(deg/hr rms)	(deg/hr/rms)	(deg/hr/ma)	(deg OA)	(deg OA)	(watts)	(watts)	(sec)	(sec)
Initial	+0.209	-0.214	+0.078	0.001	0.004	349.58	3.10	2.97	6.6	3.3	14.4	44
Post Cycle # 1	-0.209	-0.109	+1.346	0.005	0.005	419.55	3.07	2.88	6.8	3.3	14.2	46
Post Cycle # 2	+0.008	-0.271	+1.401	0.001	0.009	349.69	3.04	2.92	6.9	3.2	13.6	46
Post Cycle # 3	+0.288	-0.407	+1.423	0.001	0.010	349.26	3.07	2.92	6.8	3.4	14.0	45
Post Cycle # 4	+0.236	-0.281	+1.769	0.003	0.002	349.40	3.16	2.99	6.8	3.4	14.0	45
Post Cycle # 5	+0.487	-0.190	+1.710	0.002	0.005	349.96	3.12	2.97	6.8	3.4	14.0	44
Post Cycle # 6	+0.192	-0.346	+1.432	0.002	0.006	350.40	3.12	2.97	6.8	3.4	14.5	44
Post Shock	+0.045	-2.92	+1.759	0.002	0.004	349.80	3.12	2.97	6.8	3.4	14.3	44
Post Vibration	+0.255	-0.830	+1.917	0.002	0.002	349.96	3.12	2.97	6.8	3.4	14.4	44

Table 4. GG334S, Unit No. 4 Performance Data

Parameter	Test Results		Contract Requirement
	Before Environments	After Environments	
General Parameters			
Gyro Transfer Function	9.6 volts/rad	9.88 volts/rad	Record only
Damping	2.44×10^5 dyne-cm-sec	2.44×10^5 dyne-cm-sec	2.5×10^5 dyne-cm-sec (min)
Gimbal Freedom	+3.1 deg	+3.12 deg	+3.0 deg (min)
	-2.97 deg	-2.97 deg	-3.0 deg (min)
Operating Temperature	180.9°F	180.9°F	180°F nominal
Spinmotor			
Start Power	6.6 watts	6.8 watts	None
Run Power	3.3 watts	3.4 watts	4.0 watts (max)
Run Up Time	14.4 sec	14.4 sec	Record only
Run Down Time	44 sec	44 sec	Record only
Pickoff			
Sensitivity	24.3 volts/rad	24.4 volts/rad	26 volts/radian (nominal)
Null Voltage	3.4 mv	3.7 mv	None
Torquer Scale Factor	349.58	349.7	400 ± 10% deg/hr/ma
SMRD Output Signal	8 mv	9.1 mv	10 mv - 400 Hz (nominal)
Drift Parameters			
Fixed Torque	+0.209 deg/hr	+0.255 deg/hr	±0.40 deg/hr*
MU_{IA}	-0.214 deg/hr/g	-0.83 deg/hr/g	±0.46 deg/hr/g*
MU_{SRA}	+0.078 deg/hr/g	+1.917 deg/hr/g	±0.50 deg/hr/g*
RMS Drift Stability	0.096 deg/hr/rms	0.098 deg/hr rms	0.015 deg/hr
Drift Stability (Cooldown)			
Fixed Torque (rms)	0.10 deg/hr	waived	0.03 deg/hr
MU_{IA} (rms)	0.086 deg/hr	waived	0.05 deg/hr
MU_{SRA} (rms)	0.025 deg/hr	waived	0.05 deg/hr
Random Drift			
OAV	0.001 deg/hr	0.002 deg/hr	0.01 deg/hr
IAV	0.004 deg/hr	0.002 deg/hr	0.01 deg/hr
Elastic Restraint	-0.099 deg/hr/mr	-0.105	0.08 deg/hr
Anisoelastic Coefficient			
100 Hz	0.11 deg/hr/g^2		0.15 deg/hr/g^2
300 Hz	0.002 deg/hr/g^2		0.15 deg/hr/g^2
400 Hz	0.011 deg/hr/g^2		0.15 deg/hr/g^2
500 Hz	0.000 deg/hr/g^2		0.15 deg/hr/g^2
1000 Hz	0.000 deg/hr/g^2		0.15 deg/hr/g^2
1300 Hz	$+0.011$ deg/hr/g^2		0.15 deg/hr/g^2
1700 Hz	-0.022 deg/hr/g^2		0.15 deg/hr/g^2
2000 Hz	-0.032 eeg/hr/g^2		0.15 deg/hr/g^2
Resistances (@ Operating Temperature)			
Spinmotor A-C	39.5 homs	39.6 ohms	Record only
B-C	38.5 ohms	38.4 ohms	Record only
Signal Generator			
Primary	33.4 ohms	32.3 ohms	Record only
Secondary	164.1 ohms	164.0 ohms	Record only
Torquer	166.4 ohms	166.3 ohms	137 ohms nominal
Sensors	780 ohms	780 ohms	780 ohms nominal
Heaters			
Warm Up	264.6 ohms	265.2 ohms	265 ohms, nominal
Control	137.0 ohms	137.0 ohms	140 ohms, nominal
SMRD	827 ohms	826 ohms	Record only
Balance Pan	53.4 ohms	53.4 ohms	Record only
Inductances (@ Operating Temperature)			
Signal Generator			
Primary	1.82 mh	1.85 mh	Record only
Secondary	2.22 mh	2.20 mh	Record only
Torquer	1.90 mh	1.80 mh	0.7 mh (nominal)
Resistances Test (at 180°F)			
Sensor		778.7 ohms	Record only

*Before environments only

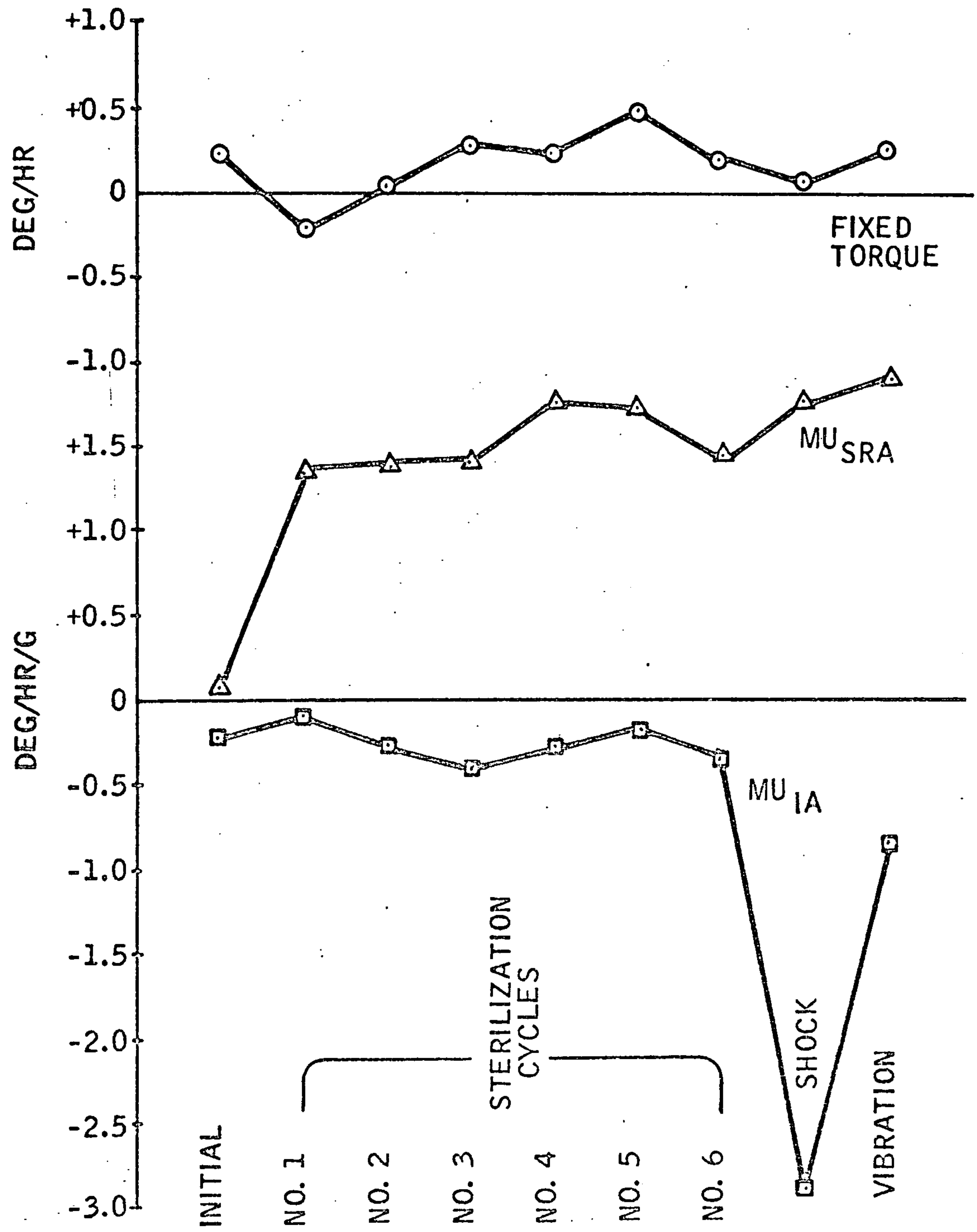

Figure 1. GG334S S/N A4 Environmental Test Torque History

COIL CUP PROCESSING PROBLEM

A problem was discovered with the processing of the additional coil cups needed for gyro No. 5. When these coil cups were wound, the operator used different wire spacing and a different technique to provide insulation at the cross-over points between coils. This caused the coil cups to develop an insulation breakdown between the secondary and the torque generator. The breakdown occurred after the coil cup was mounted on the gimbal, after which the cup was replaced with one correctly processed.

TEST PROGRAM MODIFICATIONS

Certain modifications in the test program were proposed and accepted by JPL. These were intended to streamline and improve the test program. Some additional tests were added at selected points in the test program and some were dropped. The specific changes were:

- Torquer scale factor linearity was changed to a design proof test on one unit. Torquer scale factor stability at a given current level was added as a design proof test.

- Two-hour room temperature cooldowns were allowed rather than the 24-hour cooldown required. This shortened the testing and made it compatible with JPL in-house procedures.

- Low-frequency anisoelastic coefficient measurements were discontinued because of test problems.

- Miscellaneous parameter checks on such parameters as resistances and inductances, which were unlikely to change, were dropped in favor of spinmotor and drift checks, parameters which could change due to environments.

- Repetitive measurements were eliminated at the conclusion of testing.