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HONEYWELL

Report No. 20584-QR6

SIXTH QUARTERLY PROGRESS REPORT

For Period January 1, 1968 to April 1, 1968

STERILIZABLE WIDE ANGLE GAS BEARING GYRO FGG334S

California Institute of Technology
Jet Propulsion Laboratory
Contract No. 951529

HONEYWELL | Aerospace Division

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NOTICE

ABSTRACT

This document is the sixth Quarterly Progress Report, covering the period 1 January 1968 to 1 April 1968, for the Wide Angle Gas Bearing Gyroscope FGG344S, submitted in accordance with contract No. 951529. This report defines progress to date and technical problems encounted and solved.

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TABLES

SECTION I
PROGRESS AND FUTURE PLANS

PROGRESS

- Coordination meetings were held at J. P. L. and bi-weekly progress reports were implemented.
- Motor lockup due to moisture was eliminated.
- Motor lockup due to organic vapor and particulate contamination was minimized.
- Three motors were vibrated and shocked per specification and are ready for installation in the gimbals.
- Two additional motors were fabricated with the anti-lockup geometry and are ready for shock and vibration acceptance tests.

FUTURE PLANS

- Complete organic contamination investigation.
- Complete gyro build and begin test schedule.

SECTION II
DISCUSSION

J. P. L. COORDINATION MEETING

A meeting was held at J. P. L. on 1 February 1968 to discuss the status of the GG334S/GG159E gyros. The purpose of the meeting was to discuss in detail the moisture lockup problem and the proposed solution. So that J. P. L. will be able to more closely follow the program progress it was agreed that brief progress reports would be provided by Honeywell every two weeks.

MOISTURE LOCKUP

The moisture lockup problem (first discussed in the fifth quarterly progress report) is an inability to restart the motor when it has been stopped after continuous running for periods between 10 and 100 hours. Moisture in the gimbal parts evaporates into the gimbal atmosphere and then is pumped into the gas bearing where it condenses. This condensation allows the rotor to wring to the shaft when the motor slows down and the parts approach each other. The point of wringing in is indicated by an abrupt stopping of the rotor on rundown. The motor can be restarted if sufficient time is allowed for the water to evaporate; and the starting voltages quickly return to original values with a few quick starts and stops. Running the motor for a few hours will repeat the cycle.

Moisture lockup has been eliminated by using patterns which pump gas through the bearing assembly. By pumping gas through the assembly of thrust and journal bearings, the moisture is carried away faster than it can condense.

Testing has shown the optimum pattern for preventing moisture lockup is the assymetrical journal pattern. In this approach, one of the two journal patterns is made longer than the other. This assymetry creates a pressure differential along the axial length of the journal bearing resulting in axial gas flow.

The assymetrical journal motor was tested under adverse moisture conditions with excellent results. After cleaning and assembly, the motor was mounted in a small air tight chamber, Figure 1, and its performance monitored at the ambient relative humidity (RH) condition of 40 percent. Then, successive incremental amounts of water were added to bring the RH to 90 percent. Relative humidity was measured with a Honeywell Q-464 relative humidity sensor. No moisture lockup was observed. Table 1 summarizes the results.

Table 1. Moisture Lockup Sensitivity of Optimized Assymetrical Journal Design

Relative Humidity %	Running Hours	Motor Performance
40	1.0	No Lockup
50	3.0	No Lockup
60	2.0	No Lockup
70	2.0	No Lockup
80	2.0	No Lockup
90	2.0	No Lockup

This testing verifies that the assymetrical journal pattern solves the moisture lockup problem. Investigation of water absorption and desorption characteristics of organic materials is continuing, however, in order to optimize materials and processes for this gyro and for future related efforts.

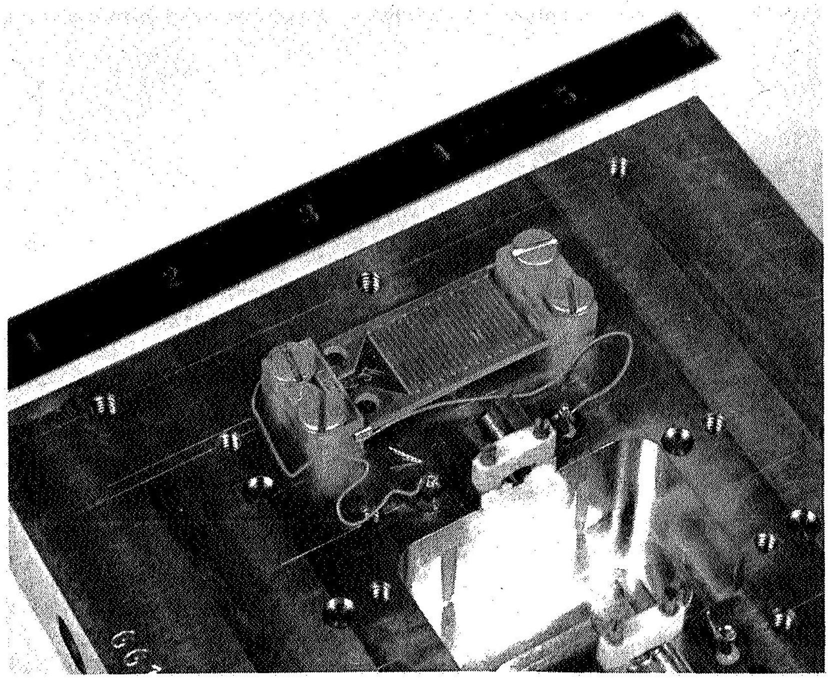

Figure 1. Vibration Fixture with Honeywell Q464 Relative Humidity Installed

ORGANIC VAPOR AND PARTICULATE CONTAMINATION

Two gas bearing spinmotors, with a similar motor stator configuration, have had confirmed failures due to particulate contamination from the stator. It may also be possible that organic vapors from the stator could saturate the gimbal atmosphere and condense inside the bearing in a manner similar to that experienced with water vapor. As a result, two courses of action have been initiated. First, the GG334S stator is being sealed in a metal enclosure to minimize the possibility of particles or organic vapor from escaping from the stator. Second, a series of analytical tools have been and are being developed to pinpoint sources of contamination.

Design layout work on the sealed stator was completed and experimental units built and tested. Figure 2 shows the basic concept, and Figure 3 shows the completed stator. Two end shields are formed to the exact contour of the stator end turns. These are then bonded to the slot bridge and stator hub to totally enclose the stator in metal, except for the bond-lines. This approach will minimize the possibility of organic vapor and particulate contamination escaping from the stator. Consideration was also given to a solid liner for the laminated P-6 hysteresis ring as shown in Figure 2. A series of magnetics tests were conducted with the combinations shown below.

1. Sealed stator - standard H-ring rotor

air gap = 0.002"	Power	3.0 watts
	Sync Margin	7.0 volts
	Start Margin	6.0 volts
air gap = 0.004"	Power	4.2 watts
	Sync Margin	6.0 volts
	Start Margin	6.0 volts

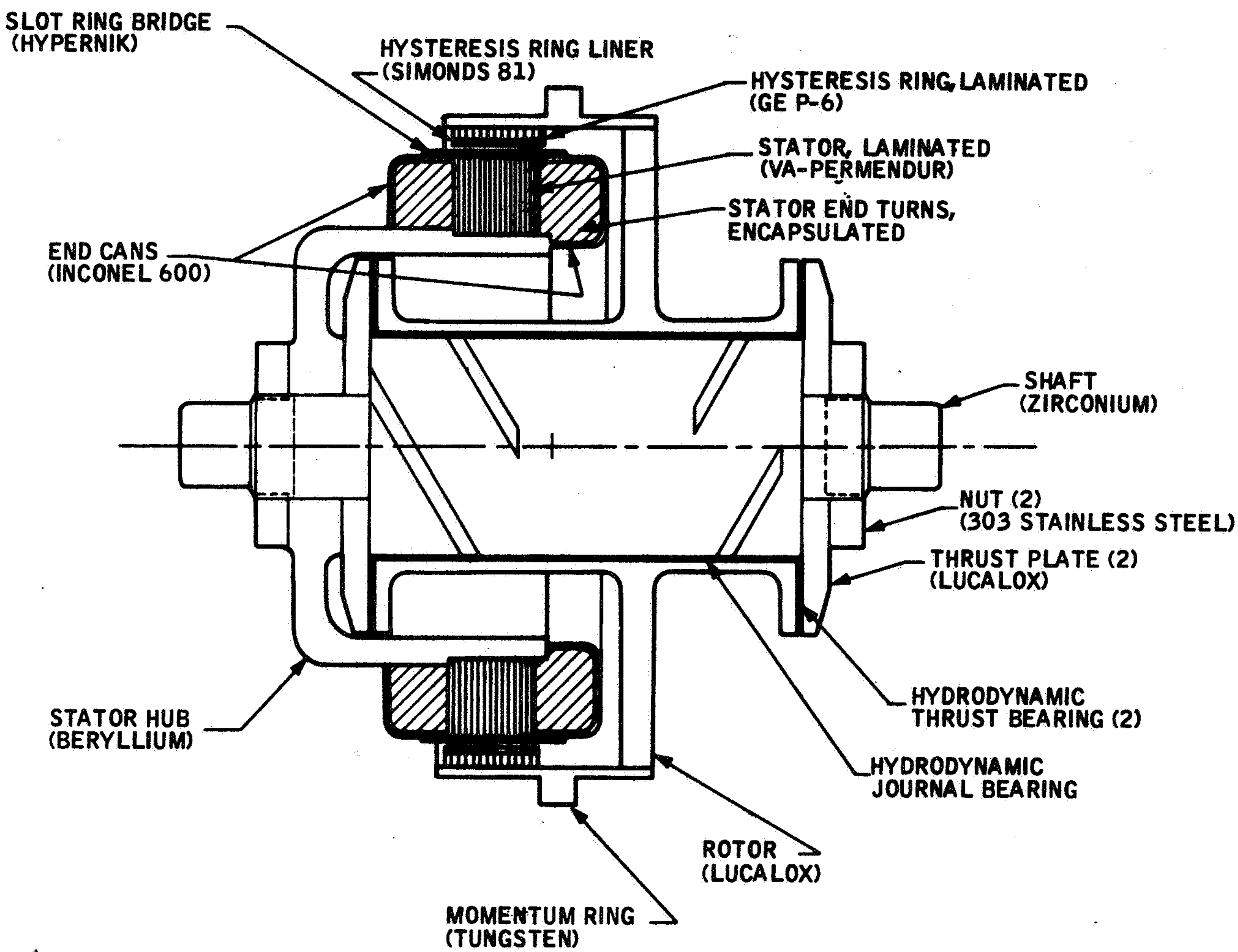

Figure 2. GG334S Gas Bearing Spinmotor

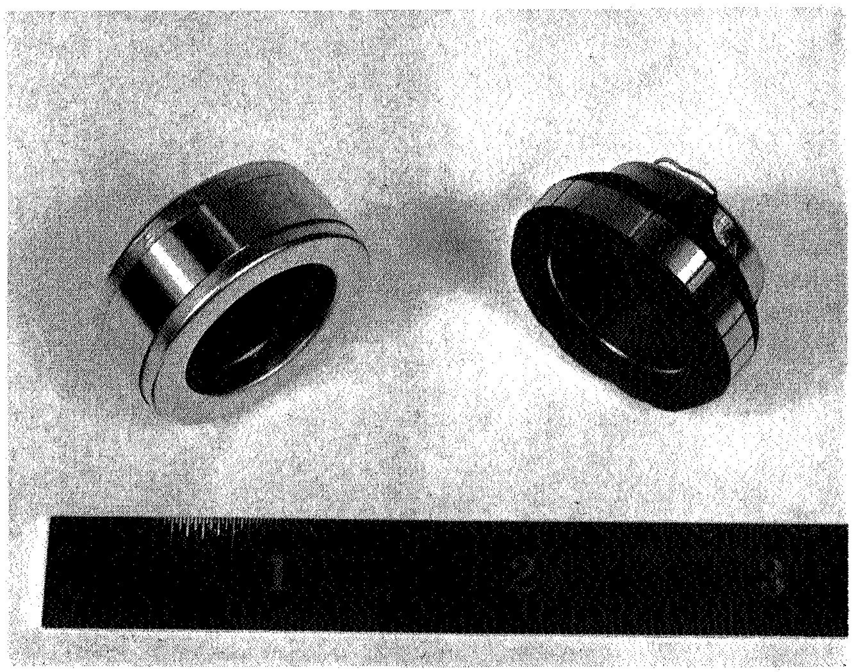

Figure 3. Encased and Standard Motor Stator

2. Sealed stator and lined H-ring

air gap = 0.001"	Power	3.6 watts
	Sync Margin	2.0 volts
	Start Margin	4.5 volts
air gap = 0.002"	Power	3.9 watts
	Sync Margin	3.0 volts
	Start Margin	5.0 volts
air gap = 0.004"	Power	4.0 watts
	Sync Margin	4.0 volts
	Start Margin	6.0 volts

It is evident from these tests that adding the slot bridge and stator end shields and reducing the air gap to 0.002 inch produces a motor with reasonable sync and start margins with acceptable power consumption. Lining the hysteresis ring is not desirable from a power standpoint. The GG334S spinmotor is being fabricated with a slot bridge and stator end shields.

The analytical methods being developed to pinpoint sources of contamination are infrared analysis, ultraviolet fluorescence, mass spectroscopy, gas chromatography, and hot-stage microscopy.

Infrared Analysis

Infrared maps of the 14 organic materials listed below have been prepared. All, except Heresite, are epoxy compounds.

6293 F natural $CaCO_3$ filled amine hardened (stator impregnant)

6293 G unfilled, amine, with diisocyanate and tetrasulfide

6293 N black dye (stator exterior coating)

7381 Bondmaster. Amine with isocyanate (stator lamination adhesive

7556 Eccobond aliphatic amine silver epoxy (electrically conductive)

6020Q, $CaCO_3$ filled amine hardened

6020Q, fluorescent dye 7921

6293 F black dye

6293 H, unfilled, amine

6293 J, anhydride, TiO_2 filler

6293 N natural 7274 ceramic fill, amine hardened

7200 Heresite, phenolic

7553 Epoxolite 293-11. Anhydride

7997-01 DK-4. Anhydride

Of these 14 materials only the first five are presently in use on the GG134/159E gimbal. The others are materials which could be substituted for existing materials if objectionable characteristics become evident.

Infrared analysis of the contamination material in two motors, from another gyro program, has positively identified the contaminant as particles of the stator impregnant 6293 F and the lamination bond material 7381. The infrared map of the contamination is shown in Figure 4. The large absorption peak at 14.5 shows the presence of the $CaCO_3$ filler from the stator impregnant. The small absorption peak at 16 shows the presence of the isocyanate from the 7381 lamination cement. With this technique, should contamination occur, source identification will be relatively simple.

Ultraviolet - Fluorescence Analysis

Since gas bearing contamination is sometimes found in too small a quantity for infrared analysis, ultraviolet fluorescence samples were also prepared to form a standard for comparative checks. The previously mentioned 14 materials, plus "Sepko" cleaning powder, have been assembled into a

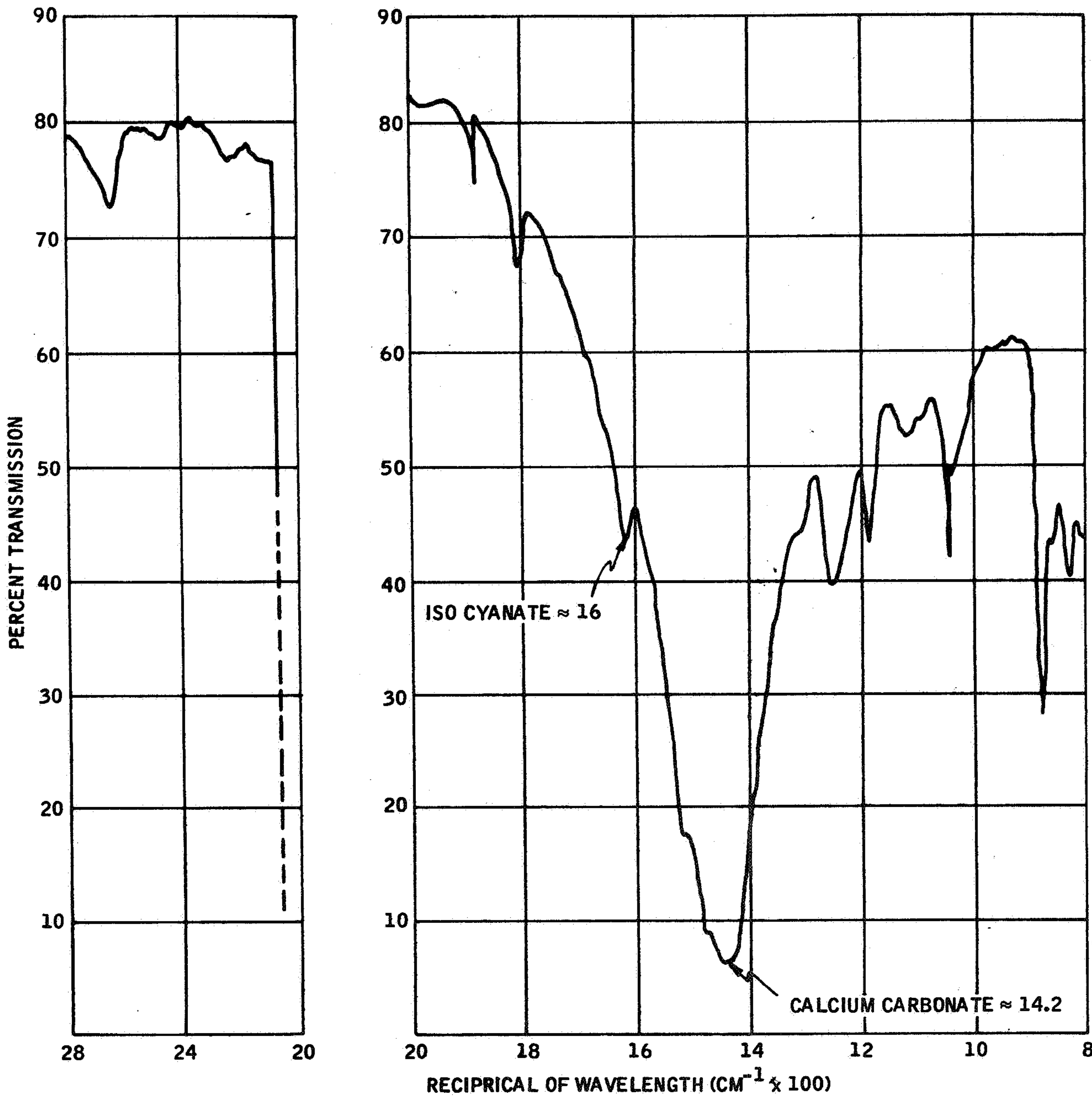

Figure 4. Sample Infrared Map

compact visual aid comparison system. This system will permit visual correlation of the contaminant with the previously assembled standard. Table 2 lists the results.

Table 2. Ultraviolet - Fluorescence of Materials Used in the GG334S/GG159E

6020Q ($CACO_3$ Filled)	Mildly Fluorescent	Mildly Fluorescent
6020Q, Fluorescent Dye	Fluorescent	Fluorescent
6243F Natural ($CACO_3$ Filled)	Mildly Fluorescent	Mildly Fluorescent
6293F Black Dye	Nonfluorescent	Nonfluorescent
6293G (Unfilled)	Mildly Fluorescent	Mildly Fluorescent
6293H (Unfilled)	Mildly Fluorescent	Mildly Fluorescent
6293J (TiO_2 Filled)	Nonfluorescent	Nonfluorescent
6293N Natural (Silicate Filled)	Mildly Fluorescent	Mildly Fluorescent
6293N Black Dye	Nonfluorescent	Nonfluorescent
7381 Bondmaster	Fluorescent	Fluorescent
7556 Eccobond	Nonfluorescent	Nonfluorescent
7200 Heresite	Nonfluorescent	Nonfluorescent
7553 Epoxilite 293-11	Nonfluorescent	Nonfluorescent
7997-01 DK 4	Nonfluorescent	Nonfluorescent
Sepko Powder	---	Mildly Fluorescent

Mass Spectroscopy

Mass spectrometer analysis will be used to sample gimbal fill gas for moisture content and organic vapor constituents. A fixture has been designed and built to permit direct gimbal gas sampling as shown in Figure 5. The gimbal is solidly clamped between the end nests with an "O" ring primary seal. A wheel puller device is used to extract the fill plug permitting the gimbal gas to enter the mass spectrometer chamber. The same fixture can also be used for gas chromatography cross checks.

Gas Chromatography

Five materials have been selected on the basis of quantity and proximity to the motors for outgassing and dewpoint tests. These materials are listed below.

- 6293F natural color, $CaCO_3$ filled, amine hardened (Stator Impregnant)
- 6293G unfilled amine hardened with diisocyanate and tetrasulfide (Epoxy Adhesive)
- 6293N black dyed, ceramic filled, amine hardened (Stator Coating)
- 7381A Bondmaster, amine hardened epoxy (Stator Lamination Adhesive)
- 7556A Eccobond Aliphatic amine hardened silver filled epoxy (Electrically conductive adhesive)

Hot-Stage Microscopy

Thermal behavior of the 14 organic materials has also been studied under a hot-stage microscope capable of 350°C. Data from this analysis is tabulated in Table 3 and will enable more rapid identification of contamination materials.

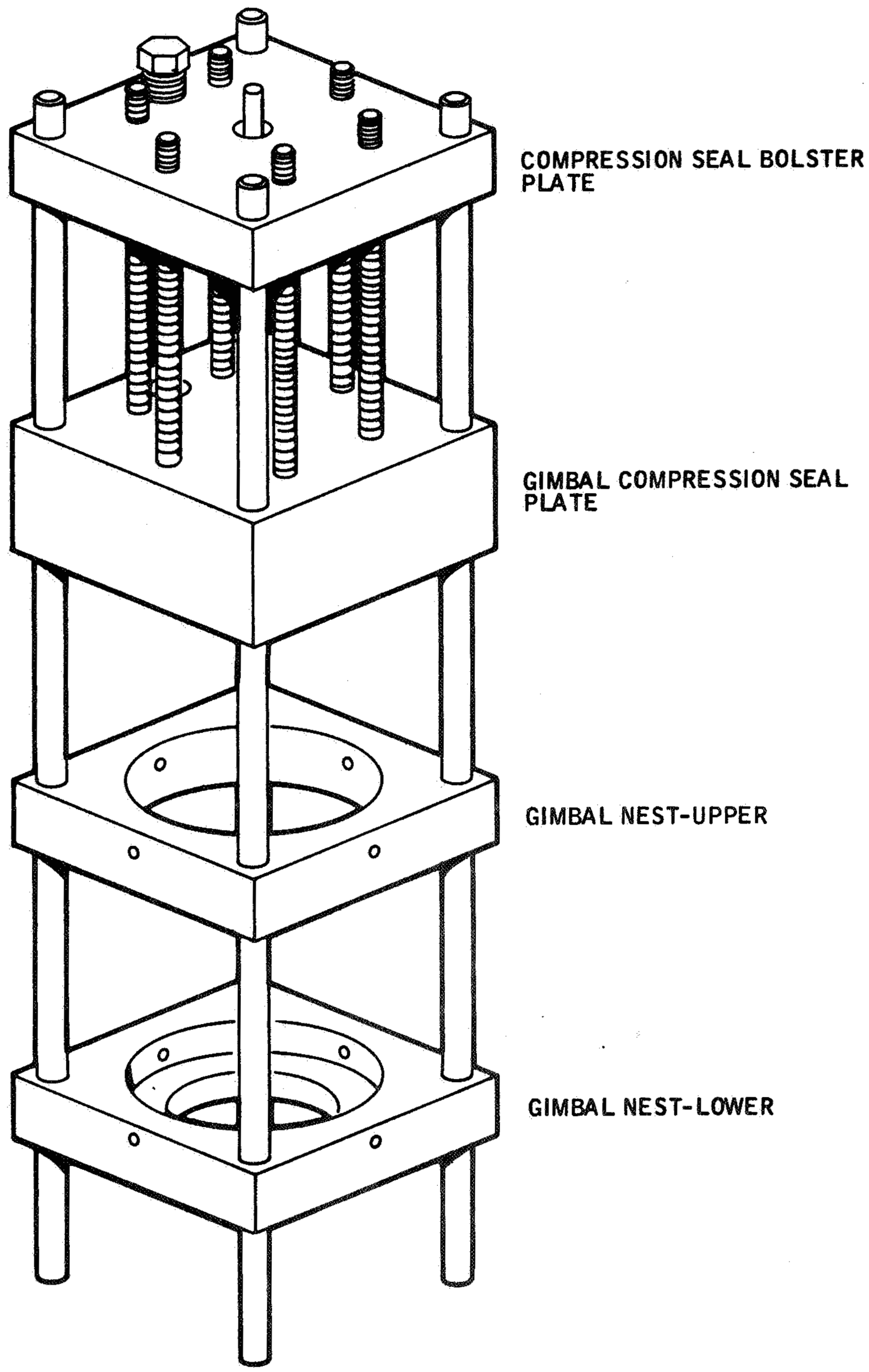

Figure 5. GG159E/GG334S Gimbal Gas Sampling Fixture

Table 3. Thermal Analysis Using Hot-Stage Microscope

Material	Initial Color	Appearance of Microscope Samples at Respective Temperatures (°C) 240°	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°
6020Q	White			Tan		Dark Tan				Brown			Brown-Black
6020Q (Fluorescent Dye)	Pale Yellow-White	Pale Yellow Tan			Tan		Light Orange-Brown			Darker Orange-Brown			Softening of Material Color Has Grey Cast
6293F Natural	White	Light Tan			Tan		Light Brown			Brown			Particles Appear Dry and Almost Black
6293F (Black Dye)	Light Grey		Tan			Darker Tan		Brown		Darker Brown			Brown to Black
6293G	White	Tan	Light Brown		Brown			Dark Brown			Black		Black but No Charring
6293H	White	Pale Tan		Light Brown		Brown		Dark Reddish-Brown					End of Test Particles Dark but No Charring
6293J	White		Slight Discoloring					Light Tan		Particles Appear Dry			Greyish-Tan
6293N Natural	Light Tannish-White	Slight Discoloring		Tan			Light Brown			Brown to Dark Brown			Particles Dark Brown - No Charring
6293N (Black Dye)	Light Grey		Slight Discoloring	Tan			Dark Tan			Brown Greyish-Brown			Greyish-Brown to Dark Brown
7381A	Clear	Tan					Brown		Softens and Discolors		Dark Brown		Softens - No Charring but Dark
7553	Light Greyish-White		Slight Discoloring		Tan		Dark Tan		Light Brown			Brown	Brown - Dark Brown
7200	Light Brown		Brown		Greyish-Brown			Dark Black-Brown					End of Test Black - No Charring
7556	Silver			Slight Discoloring				Particles Appear Dryer and Greyer			Particles Getting Holes		Discolors to Dark Grey
7997-01	Light Green			Slight Discoloring to Green				Green to Dark Green			Dark Green-Brown		Dark Green Brown-Grey

SPINMOTOR SHOCK AND VIBRATION TESTING

All GG334S spinmotors will be qualified to the vibration and shock specification prior to installation into the gimbal. Three motors, with the unsymmetrical journal pattern, have successfully passed shock and vibration. Tests of the remaining two motors will be completed within a few days. Vibration was performed to the following specification:

- Random Vibration

  Test Envelope:

0.2 g^2/cps (16.4 g rms)	300-1000 cps
-6 db per octave	1000-2000 cps
-24 db per octave	above 2000 cps
-3 db per octave	20-300 cps
-24 db per octave	below 20 cps

  Test Duration:

  3 minutes each axis.

- Random Vibration (with superimposed sine vibration)

  Test Envelope:

5.0 g rms Gaussian	15-2000 cps
2.0 g rms sine	15-40 cps
9.0 g rms sine	40-2000 cps

  Test Duration:

  Sweep 15 to 2000 cps and back in 10 minutes each axis.

- Shock

  200 g peak
  1.5 ms (half sine)
  5 times each axis

SECTION III
SCHEDULE

The gyros will be built and tested in accordance with the schedule shown. First gyro shipping is scheduled for July 1, 1968. Figure 6 shows the build schedule.

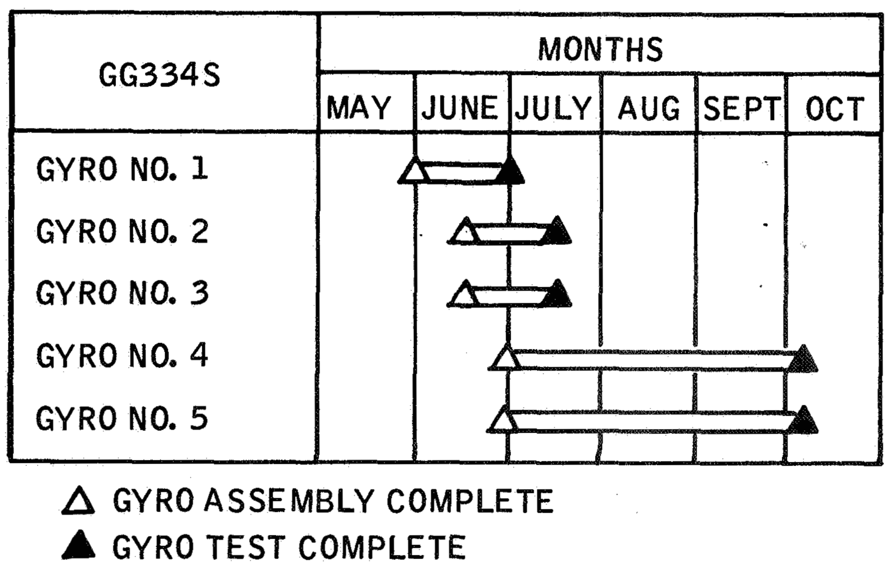

Figure 6. Gyro Build Schedule