FINAL REPORT

NIMBUS D RMP PROGRAM

CONTRACT NAS 5-10391

MAY 1967 TO MAY 1970

Prepared by

SPERRY GYROSCOPE DIVISION
SPERRY RAND CORPORATION
GREAT NECK, NEW YORK

Prepared for

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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1.0 INTRODUCTION

This is the final report on the Nimbus D Rate Measuring Package program, Contract NAS 5-10391. The program has been conducted by the Sperry Gyroscope Division of the Sperry Rand Corporation under the technical direction of the Systems Engineering Branch, Systems Division at the Goddard Space Flight Center (GSFC). The program was initiated on 9 May 1967 and officially concluded on 31 May 1970.

The specified application and functional requirements for the Nimbus D Rate Measuring Package (RMP) design were different in two key areas compared to the previous Nimbus B RMP. The Nimbus D RMP was to be the prime yaw axis rate sensor for the Nimbus D spacecraft and as such, had to mechanically and electrically interface with the new Attitude Control System (ACS) designed and developed by NASA/GSFC. A second requirement, imposed by NASA/GSFC, was to provide capability within the Nimbus D RMP to utilize either the Kearfott Alpha II ball bearing gyro or the Sperry SYG 4200 gas bearing gyro. These units are mechanically and electrically interchangeable in the Nimbus D RMP with an appropriate set of relay cards to control the starting and running logic for each instrument.

The Nimbus D RMP design is fundamentally an extension of the successful Nimbus B RMP experimental sub-system. In order to mechanically interface with the Nimbus D ACS, a new RMP housing was required. The internal mounting of the PC cards, electronic sub-assemblies and the gyros was an almost identical carryover from the Nimbus B RMP design. To comply with the necessity of interfacing two gyros, the electronics and harness were modified such that utilization of either gyroscopic instrument in the system was accommodated by simply changing two relay cards.

One prototype and two flight rate measuring packages were manufactured and delivered under this contract, each with a ball bearing gyro. A set of bench test equipment and a set of spare RMP electronics were also delivered as part of the Nimbus D Program. The gas bearing and ball bearing gyros utilized in the Nimbus D RMP's were supplied by NASA as GFE from the earlier Nimbus B RMP Program, Contract NAS 5-9571.

The objective of this program was successfully fulfilled when on 10 April 1970, the Nimbus IV spacecraft was launched with Kearfott gyro S/N 4 in Rate Measuring Package FT04 S/N 7. The RMP operated continuously for about one year as the prime yaw axis sub-system. This final report presents a description of the equipment delivered and discusses, in detail, the engineering effort associated with the integration of the Kearfott Alpha II gyro into the Nimbus RMP. Included in this document is a discussion of problems encountered with the Kearfott gyro and a summary of life data on these instruments.

2.0 OBJECTIVES AND PURPOSE OF EQUIPMENT

2.1 Objectives. The overall objective of the program was to continue the development of an advanced Long Life Rate Measuring Package, designed for a five-year useful life as a meteorological satellite control sensor. The Nimbus D RMP was designed to mechanically and electrically interface with the spacecraft ACS and have the capability of utilizing either the Kearfott Alpha II ball bearing gyro or the Sperry SYG 4200 gas bearing gyro as the rate sensor.

The basis for the Nimbus D RMP design was the successful Nimbus B RMP experiment aboard the Nimbus 3 spacecraft. Fundamentally the same design approach was taken in the development of the Nimbus D RMP as was employed in the design and development of the Nimbus B RMP. Two noteworthy modifications were introduced in the development of the Nimbus D RMP. First, the mechanical structure was modified to interface with the ACS; this required four mounting flanges and the inclusion of an optical alignment mirror mounted directly to the gyro bracket. Secondly, changes were introduced to the electronics and harness such that either the Kearfott Alpha II or the Sperry SYG 4200 gyro could be utilized as the rate sensor. Employment of either gyro in the system requires a set of relay cards which prescribes the starting and running logic for each gyro.

2.2 Purpose of Equipment. The primary function of the Rate Measuring Package is to provide rate information for the reaction wheel and gas jet torquing devices that are used to damp spacecraft oscillations and to constrain it in the required attitude with respect to the orbital plane. The Rate Measuring Package sensor, a single-degree-of-freedom, rate integrating gyro, is oriented such that the sensitive axis is inclined 45 degrees from the yaw axis in the plane of the yaw-roll axes. The rate threshold of the RMP is less than 0.1°/hr which provides resolution of spacecraft displacement about the yaw axis of less than 0.04 degree. The RMP maximum rate sensing capability is 0.2°/sec with a nominal total input power in orbit of approximately 8 watts, with the ball bearing gyro. The total input power in orbit with the gas bearing would be 3.5 watts, with the heater off.

Telemetering of key system and gyro parameters is provided on a continuous basis. A command sequence is available to operate the ball bearing gyro, heater on or off, when in orbit. Command sequences are available to operate the gas bearing gyro wheel at 12,000 or 24,000 rpm, with the heater on or off. During spacecraft launch the gas bearing gyro wheel MUST be operated at 24,000 rpm to survive boost vibration input levels.

In early 1969, (prior to the launch of the Nimbus 3 spacecraft) the decision was made by NASA/GSFC to qualify the prototype Nimbus D RMP with the Kearfott Alpha II ball bearing gyro. The two flight RMP's were also flight-qualified with the Kearfott Alpha II ball bearing gyro as the rate sensor.

3.0 DESCRIPTION OF EQUIPMENT

3.1 RMP Description

3.1.1 General. The RMP measures 6 x 6 x 6-1/2 inches and weighs approximately 9-1/2 pounds. It contains the following major assemblies.

- Floated, Rate Integrating Gyro - Electronics designed such that either the Kearfott C70-2564-015 ball bearing gyro or the Sperry SYG 4200 gas bearing gyro may be utilized.

- Six, single-sided, printed-circuit cards containing the gyro feedback electronics, gyro excitation electronics, heater controller, telemetry signal conditioning circuits, and command relay circuits.

- Inverter subassembly which provides excitation to the gyro spin motor.

- RFI assembly containing input and output filter components

- Harness assembly including four external and eight internal connectors.

- Gyro normalization assembly containing gyro calibration components.

The above assemblies are mounted in a cast aluminum support structure providing the proper mechanical alignment and thermal transfer characteristics.

Telemetering of key system and gyro parameters is available on a continuous basis. Optional command inputs are provided to cut off gyro heater power in orbit, if desired, and also to reduce the gyro spin motor voltage.

3.1.2 Test Data. Prototype and flight RMP units for Nimbus D have been manufactured and tested in general accordance with NASA/GSFC Specification for Rate Measuring Package (RMP), S-731-P-47A, dated August 30, 1967. Factory Acceptance Tests (FAT) are delineated in Sperry Test Specification T4310-10678, Factory Acceptance Test, Nimbus D RMP. Environmental tests are performed per NASA/GSFC Environmental Test Specification for Nimbus D Subsystems, S-320-N1-3-A, dated September 22, 1967.

3.1.3 Mechanical Interface

The mechanical interface of the RMP with the ball bearing gyro is described in the following sub-paragraphs as this was the configuration of the prototype and two flight systems delivered under this program.

3.1.3.1 Configuration and Weight. The configuration of the Rate Measuring Package is defined by RMP outlined drawing No. 4310-90596. The weight of the Rate Measuring Package is approximately 9.5 pounds.

3.1.3.2 Mounting. The RMP is secured to the Attitude Control System (ACS) structure by means of an integral mounting flange. (See RMP outline drawing No. 4310-90596.)

3.1.3.3 Gyro Alignment. The gyro input axis is located in the roll-yaw plane within ±2 arc minutes of an optical reference surface on the gyro assembly, and 45 degrees ±30 arc minutes from the positive yaw axis towards the negative roll axis.

3.1.4 Environmental Capabilities

3.1.4.1 Temperature

Operating temperature range	10° C to 40° C
Qualification temperature range	-5° C to 50° C
Storage temperature range	-12° C to 85° C

3.1.4.2 Vibration. The RMP is qualified at the following levels about all axes:

Sinusoidal	10g, 0-to peak, 5 to 2000 Hz (15g, 0-to-peak, 30 to 150 Hz, thrust axis only)
Random	$0.2g^2$/Hz, 20 to 2000 Hz

3.1.4.3 Thermal Vacuum. The RMP will operate within performance requirements in an ambient pressure of 10^{-5} mm Hg and at temperatures ranging from -5°C to 50°C.

3.1.4.4 Humidity. The RMP will withstand 95% relative humidity at 30° C for 24 hours without mechanical or electrical damage.

3.1.5 Rate Output Characteristics. The rate output across terminals J3-2 and J3-1 has the following characteristics:

Scale factor (unloaded):	100±5 vdc/deg/sec
Polarity:	A positive vehicle yaw rate produces a positive RMP output at J3-2
Output resistance:	2000±30 ohms
Maximum output:	±25 vdc
Noise (max):	20 mv peak-to-peak

The rate output return, J3-1, must ultimately connect to the same ground as the other RMP dc returns, in order for the indicated rate telemetry (T/M) channels to function.

The rate output circuitry is basically isolated from the remainder of the RMP except for the resistive loads provided for the indicated rate T/M signal conditioner circuits.

3.1.6 Electrical Interface

The following paragraphs provide electrical interface data for the ball bearing configuration RMP. Table 1 contains a summary of electrical interface connections and characteristics.

3.1.6.1 Electrical Connectors. Three Cannon-type DM connectors provide electrical interconnections between the RMP and the spacecraft harness. A fourth connector routes test points to the bench test equipment. Connector designations, types, and functions are as follows:

Designation	Type	Function
J1	DDM-50P	Power and clock inputs
J2	DBM-25P	Telemetry outputs
J3	DEM-9P	Rate output
J4	DAM-15S	Bench test equipment testpoints

Table 1. Numbus D RMP Interface Characteristics

Connector Pin	DC Volts	Amps	Impedance (Ohms) Source	Impedance (Ohms) Load	Remarks
J1-1	-1	0.12	Note 1	230	RMP ON command pulse (+)
-2	-22.5			230	(-)
-3	-1			210	RMP OFF command pulse(+)
-4	-22.5				(-)
-5	-1				LOWER MOTOR VOLTAGE command pulse (+)
-6	-22.5				(-)
-10	-24.5	0.5		52	Emergency off input
-13	± 1.3 max	±0.025 max	1K min	50	Gyro torques input
-14	-	-	-	-	Gyro torques return
-15	Short	-	-	-	Bench test equipment interlock
-16		-	-	-	
-18	-				T/M power return
-19	-24.5	1.4 max	-	-	Relay power input
-20	-		-	-	Relay power return
-21	-	1.0 max	-	-	Inverter power return
-22	-		-	-	Inverter power return
-23	-	-	-	-	Chassis ground

Table 1. Numbus D RMP Interface Characteristics (Cont.)

Connector Pin	DC Volts	Amps	Impedance (Ohms)		Remarks
			Source	Load	
J1-24	-	-	Note 2	-	Chassis Ground
-25	-	-		-	
-26	-	-		-	
-27	-1	0.12	Note 1	230	HEATER OFF command pulse (+)
-28	-22.5				(-)
-29	-1				MOTOR ON command (+)
-30	-22.5				(-)
-34		0.005		5K	T/M power input
-35		-	Note 2	-	
-37		1.0 max	-	25	Inverter power input
-38			-		
-40	-19.6	0.006	-	2.2K min	400Hz clock input, phase A
-41	-19.6	0.006	-		400Hz clock input, phase B
-42	+4.5	below 0.001	-	10K min	5kHz clock
J2-1	-10 max	below 0.001	5K(Note 3)	Note 4	Relay status No. 1 T/M
-2			5K		2
-3			3K		Primary voltage
-4			22K		Motor voltage
-5			2K		Motor current
-7			21K		Heater power
-8			Note 1		T/M return
-9	-10 max	below 0.001	10K(Note3)	Note 4	Gyro temperature T/M
-10			10K		Subsystem temperature T/M
-11	-10	below 0.001	27K	Note 4	High resolution indicated rate T/M
-12			26K		Medium resolution indicated rate T/M
-13			13K		Low resolution indicated rate T/M
J3-1		below 0.001			Rate signal output
-2	+25 max	below 0.001	2K	2.2Meg	Rate signal return
-6	+10	0.001		10K	+10 vdc power input
-7	-10	0.001		10K	-10 vdc power input

NOTES:
1. During pulse, 30 ohms; otherwise, 10K ohms
2. No connection to Nimbus spacecraft
3. DC impedance given (shunted by 2.2 ufd capacitor)
4. During 160-microsecond sampling period, 1 megohm; otherwise 10 megohms

3.1.6.2 Power Requirements

- Power Inputs. There are three -24.5 vdc power inputs to the RMP. Dual connections for each input are provided as follows:

T/M power	-24.5 vdc	J1-34
	Return	J1-18
Inverter power	-24.5 vdc	J1-37, 38
	Return	J1-21, 22
Relay Power	-24.5 vdc	J1-19
	Return	J1-20

- Input Power Regulation. Spacecraft regulated supply characteristics are nominally as follows:

Voltage regulation	24.5±0.5 vdc
Ripple	100 millivolts, peak-to-peak
Power distribution voltage drops	0.5 vdc max.

- Power Consumption. Power consumption of the RMP under various conditions of operation is:

RMP turn-on (electronics and heater full on)	26.0 w max
Gyro wheel turn-on (heater full on)	31.0 w max
Gyro wheel at sync (heater full on)	30.0 w max
Steady-state in orbit	
Heat sink at 10° C	11.3 w nom
Heat sink at 25° C	9.0 w nom
Heat sink at 40° C	6.8 w nom
Steady-state, sea-level ambient, 25° C	20 w nom
Steady-state, heater off	5.0 w max
Steady-state, heater off, lower motor voltage.	4.2 w max

The required input current during RMP turn-on is given in the turn-on current transient curve, (figure 1).

- Input Voltage Limitations. The RMP will withstand indefinitely a rise in dc line voltage up to -35 volts.

- Loading Characteristics. As shown in figure 2, the T/M, inverter and relay power loads are not completely isolated from each other, although they are isolated from the RMP chassis.

The T/M power load is resistive, and varies with RMP status and temperature. Its minimum value is not less than 5000 ohms.

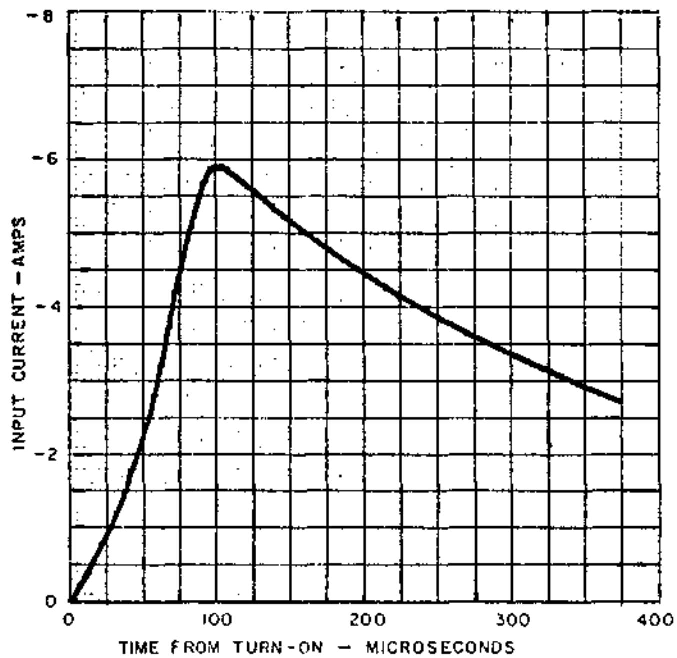

Figure 1. RMP Turn-On Current Transient

The inverter power load (load B in figure 2) consists of the gyro motor, gyro heater, and electronic loads. The inverter input circuit contains an RFI filter; the capacitors in the filter are charged whenever the bus is energized. The gyro heater has a minimum resistance of 23 ohms and is energized by the supply voltage during gyro warmup. When the gyro is within approximately 1° F of operating temperature, the heater is switched on and off at a 8-kHz repetition rate, the duty cycle adjusting itself to the heat losses in the gyro.

The relay power input feeds load A as shown in Figure 2. The load consists of four relay coils having a combined minimum value of 52 ohms, and exists during an RMP OFF command.

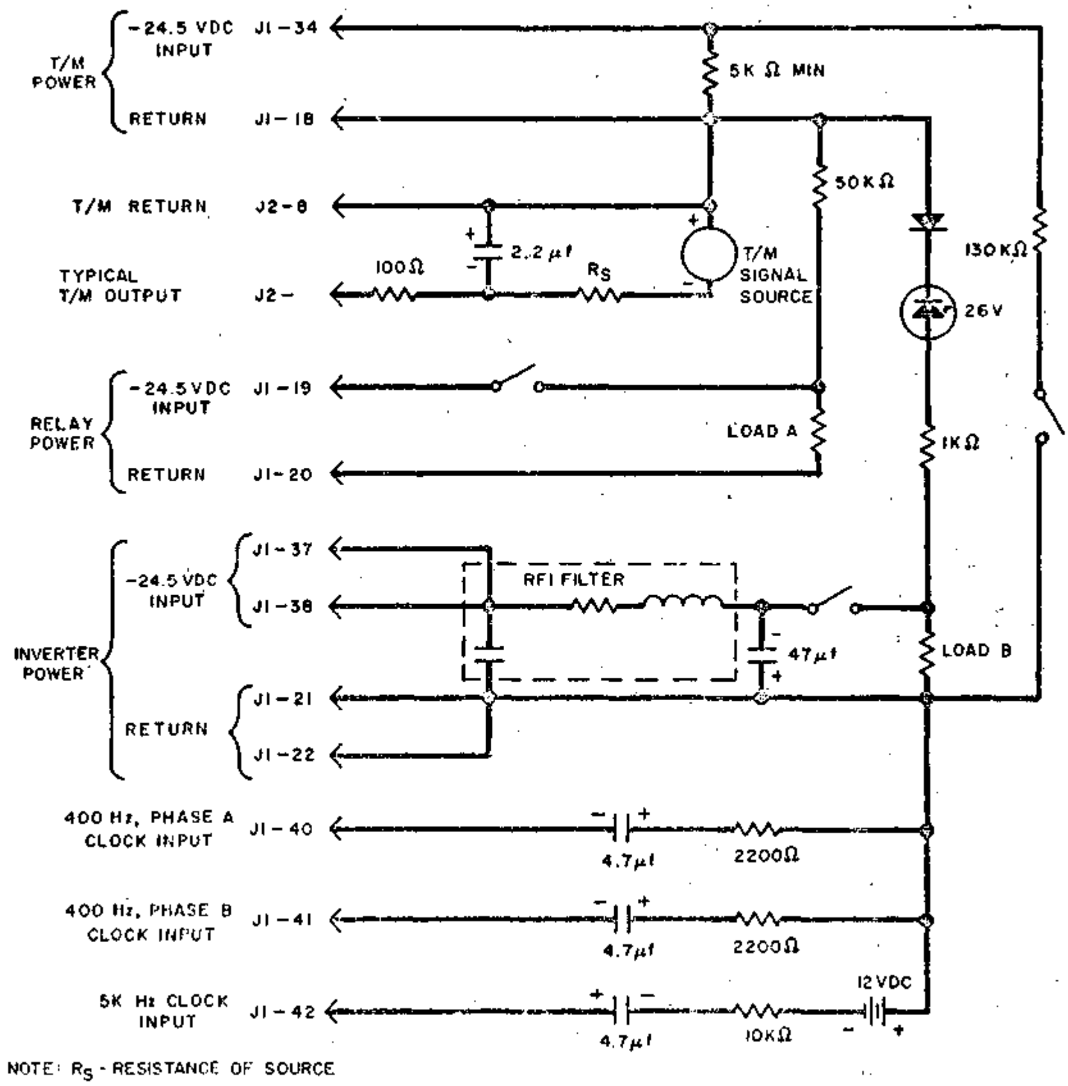

Figure 2. DC Power and Clock Input Interface

3.1.6.3 Reference Signal Inputs.

The RMP requires three, square-wave, reference frequency inputs from the spacecraft command clock subsystem, and a ± 10-vdc input from the control logic subsystem.

- 400-Hz Reference Signals. The two phases of the 400-Hz square-wave reference signals are connected to the RMP as follows:

Phase A	J1-40
Phase B	J1-41

The load on both reference signal inputs is 2200 ohms, capacitively coupled. As shown in figure 2, reference signal returns are via the inverter power returns, pins J1-21 and J1-22.

The sources for the two 400-Hz square-wave inputs should have no-load output amplitudes of -23.5±1.5 volts and -1.5±1.0 volts, with source impedances of 275 ±25 ohms. Phase B should lead phase A by 90 ±2 degrees. The no-load transition times should not exceed 5 microseconds. The square waves should each be symmetrical within 0.5 percent.

- 5-kHz Reference Signal. The 5-kHz square-wave reference input is terminated at J1-42. The load has a minimum value of 10K ohms, capacitively coupled. Signal return is via the inverter power returns, J-21, and J1-22, as shown in figure 2.

The source for the 5-kHz input should have no-load output amplitudes of ±5.25±0.75 volts and ±0.20 ±0.15 volt, with a source impedance of 1730 ±200 ohms. The square wave should be symmetrical within 3 percent, and have no-load transition times of less than 6 microseconds.

If any other subsystems require the same 5-kHz source, their combined loads should not be less than 10K ohms. Shunt capacitance across the source due to cabling, and other subsystems, should not exceed 3000 pf.

- ±10-Volt DC Inputs. The RMP requires +10-volt and -10-volt dc inputs which are applied to terminals J3-6 and J3-7 respectively. A 50K-ohm load bridges the inputs. The dc inputs should have the following characteristics:

Voltage regulation	
Source resistance	100 ohms max

3.1.6.4 Command Inputs Five command inputs provide the following functions:

Command	Connector Termination	Function
RMP ON	J1-1 J1-2	Applies power to gyro heater, torque feedback loop, and all other RMP functions, except gyro spin motor
RMP OFF	J1-3 J1-4	Removes all power to RMP, except full-time telemetry. Resets all latching relays.
Motor ON	J1-29 J1-30	Energizes gyro spin motor.
Low motor voltage (optional)	J1-5 J1-6	Reduces spin motor voltage from 29 to 24 volts.
Heater OFF (optional)	J1-27 J1-28	Removes dc from the gyro heater controller

The load for each command input is shown in figure 3.

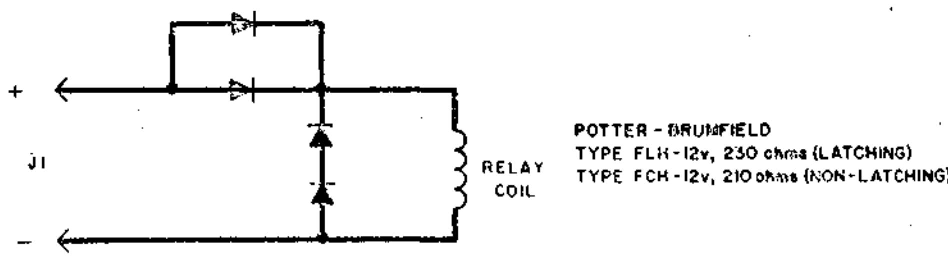

Figure 3 Command Input Load

3.1.6.5 Telemetry Channels. Twelve analog T/M channels are provided to monitor RMP data. Their outputs are available at connector J2. The common T/M return is at J2-8 which connects to the T/M power return (J1-18, figure 2). Table 2 lists T/M functions and output terminations as well as signal source resistance and power source. Any, or all, of the T/M outputs can be shorted to ground or each other, without adversely affecting RMP operation.

The T/M signal characteristics are:

Voltage range (useful):	0 to -6.4 vdc
Voltage range (maximum):	+0.8 to -10 vdc
Signal source resistance:	(Refer to table 2.)

B

Each T/M channel is shunted to the T/M return by a 2.2 ufd capacitor to minimize errors during the sampling period and to reduce noise levels.

Table 2. RMP Telemetry Data

Channel	Terminal	Source Resistance (R_S ohms)	Power Source
Relay status No. 1	J2-1	5K	Spacecraft
Relay status No. 2	-2	5K	Spacecraft
Primary voltage	-3	3K	Switched
Motor voltage	-4	22K	Switched
Motor current	-5	2K	Switched
Gyro sync	-6	27K	Switched
Heater power	-7	21K	Switched
Gyro temperature	-9	10K	Spacecraft
Package temperature	-10	10K	Spacecraft
Indicated rate, High resolution	-11	27K	Switched
Indicated rate, medium resolution	-12	26K	Switched
Indicated rate, low resolution	-13	13K	Switched

NOTES: 1. J2-8 is common T/M return for all channels.

2. Switched indicates T/M channel is inactive in RMP off mode; spacecraft indicates that T/M point is active whenever spacecraft power is on.

3. Gyro/Sync is not functional in this RMP which uses Kearfott gyro.

3.1.7 Performance and Detailed Design Data

3.1.7.1 Performance Characteristics. The following RMP performance characteristics apply only when the ball bearing gyro is at its operating temperature and in a 1-g environment.

Item	Characteristic
Linearity	
At input rate of 0 to ±0.06 deg/sec	± 5%
At input rate of ±0.06 to ±0.2 deg/sec	±10%
Threshold	0.1 deg/hr max.
Initial bias	0.1 deg/hr max.
Bias drift	0.7 deg/hr/month max.
Hysteresis	0.2 deg/hr max. for rates below 0.1 deg/sec.
Dynamic Response	
Time Constant	1.0 sec. max.
Overshoot	25% max.
Output noise	20 millivolts peak-to-peak max.
Conducted noise	50 millivolts peak-to-peak (across 0.1 ohm inserted in -24.5 vdc inverter return)
Mass unbalance	1.0 deg/hour/G max. along each axis
Scale factor	100 volts per deg/sec (up to 0.2 deg/sec)
Polarity	For positive vehicle yaw rates, the output signal is positive.

3.1.7.2 Rate Loop. Because of the relatively high gyro damping and narrow loop band-width requirements, no stabilization network is needed. The frequency-dependent terms in the electronics block are due to noise filter capacitors shunting the rebalance current readout resistor.

3.1.7.3 Parameters

- Gyro.

Gyro gain, H/D	12.4
Gyro time constant, t_G	6.4×10^{-3} sec
Pickoff gradient, Kp	2.1 mv/arc minute
Torquer scale factor, K_T/H	72 deg/hr/ma
Float displacement limit	
stops, θ max	2.4 degrees

- Electronic Circuits

Amplifier gain, K_A	
Small signal	0.27 ma/mv
Large signal	0.19 ma/mv
Output resistor, R_O	
Small signal	2000 ohms
Large signal	1900 ohms
Output time constant, t_A	
Small signal	0.015 sec
Large signal	0.027 sec
Zener diode limiting of	±25 vdc max
Output signal, e_o,	See notes

NOTES: 1. Small signal defined as e_o less than 6 vdc; large signal defined as e_o greater than 6 vdc.

2. The two values as given for small and large signals derive from the non-linear loading of indicated rate T/M circuits, caused by output limiter diodes. They are not dual values but represent the changes in slope of their respective graphs, at the output voltage level indicated.

- Overall Loop.

RMP scale factor, e_o/ϕ_{in}, 100 volts/deg/sec

3.1.7.4 Characteristic Equation. Utilizing the small signal values, the roots for the characteristic equation are as follows:

$$S = -11.6, \ -24.5, \ -153$$

These values represent an overdamped system with a primary time constant of 0.11 second.

3.1.7.5 Mechanical and Thermal Packaging Considerations

RMP packaging characteristics are specified under the following subjects:

- Gyro mounting, alignment and heat transfer
- Electronic circuit packaging and heat transfer
- Outgassing materials
- Temperature protection

3.1.7.5.1 Gyro Mounting, Alignment, and Heat Transfer. The gyro is flange-mounted in a separate aluminum bracket. A clamp and an adapter ring are used to retain the gyro against the ground mounting surface of the bracket. The ring is tapered to permit adjustment of the gyro input axis (IA) alignment about the spin axis (SA). To achieve IA alignment about the output axis (OA), the gyro and adapter ring are rotated as required. By this means, the gyro is accurately aligned to the aluminum bracket. An accurately machined optical alignment mirror is mounted directly on the gyro bracket to provide an optical reference surface which is parallel to the gyro IA-SA plane within ±1 arc minute. Lord isolators, with thermal conducting grease applied, are then inserted into four bracket mounting holes; the bracket and gyro are then mounted to the main body (casting) of the RMP. This arrangement has several advantages as follows:

- Heat Transfer - The gyro bracket is mounted to the casting at a point in close proximity to the spacecraft structure thermal sink thus keeping the thermal impedance to the designed value.

- Alignment - The gyro IA is aligned to the optical reference surface within ±1 arc minute about the SA and within ±15 arc minutes about the OA. The gyro IA alignment transferred to the RMP flange and locating holes is within ±30 arc minutes about both axes.

- Vibration Isolation - The Lord isolators provide vibration isolation for the gyro. Based on actual tests conducted at Sperry, the amplification factor at resonance of the gyro bracket has been reduced from 20:1, hard-mounted, to less than 3:1 with the isolators. (See Sperry Report #CA 4216-0863 dated July 1967.)

- Alignment Calibration - The optical alignment mirror surface, which is visible through an aperture in the RMP casting, allows for periodic measurement of the gyro axes alignment with respect to the spacecraft axes.

3.1.7.5.2 Electronic Circuit Packaging and Heat Transfer. The configuration of the RMP is such that by removing one sheet metal cover plate, all six printed circuit boards are easily accessible. In addition, the inverter subassembly is also visible and its mounting location is in close proximity to the mounting flange for minimum thermal impedance and maximum support under vibration.

The component side of each printed circuit board is a gold-plated copper surface which provides low thermal impedance to the card bracket. The heat is conducted along the copper surface to the card bracket and then to the main casting. The card bracket is rivited to the card and cemented with a thermal-conducting adhesive. The other side of each board contains only printed circuit wiring.

The RMP does not require pressure or vacuum seals to meet environmental test and operational requirements since all components are either individually sealed or encapsulated. Maintainability is high because components and modules are readily accessible for replacement.

3.1.7.5.3 Outgassing Materials. Table 3 defines the outgassing materials, their quantities, and where used:

Table 3 Outgassing Materials

Materials	Quantity	Where Used
Hysol PC-22	300 square inches x 0.03 in thick	All cards and inverter, RFI bracket
Hysol PC-22	6 square inches x 0.03 in thick	Gyro normalization package
LCA-4 Epoxy Resin	0.1 oz	All screws and washers
Wakefield Delta Bond 152	0.2 oz	Mounting of all electrical components
Emerson Cummings TC-4 Thermal Compound	0.1 oz	Mounting of all sub-assemblies; gyro bracket grommets
Black Oxide Finish per MIL-F-495	24 square inches x 0.0005 in thick	All exterior surfaces of gyro
Epoxy Enamel Paint, Cat-A-Lac #463-3-8 Flat Black	210 square inches x 0.005	All exterior surfaces of RMP

3.1.7.5.4 Temperature Protection. A thermal switch on the gyro prevents damage from overheating by the heater. Contacts open at 175 ±8° F and close at 145 ±8° F.

Both the gyro and the RMP casting contain thermistors for monitoring the temperature.

3.2 Kearfott Alpha II Gyro Design and Description

3.2.1 Background. This section provides a design and performance summary of the Kearfott Alpha II gyro which is used in the rate sensor unit of the Rate Measuring Package. A more detailed description is contained in Appendix I. Figure 4 shows, the size and shape of the Alpha II gyro.

This series of Rate Integrating Gyro has been used successfully in the Mariner Space Probe and Numbus B and C space programs.

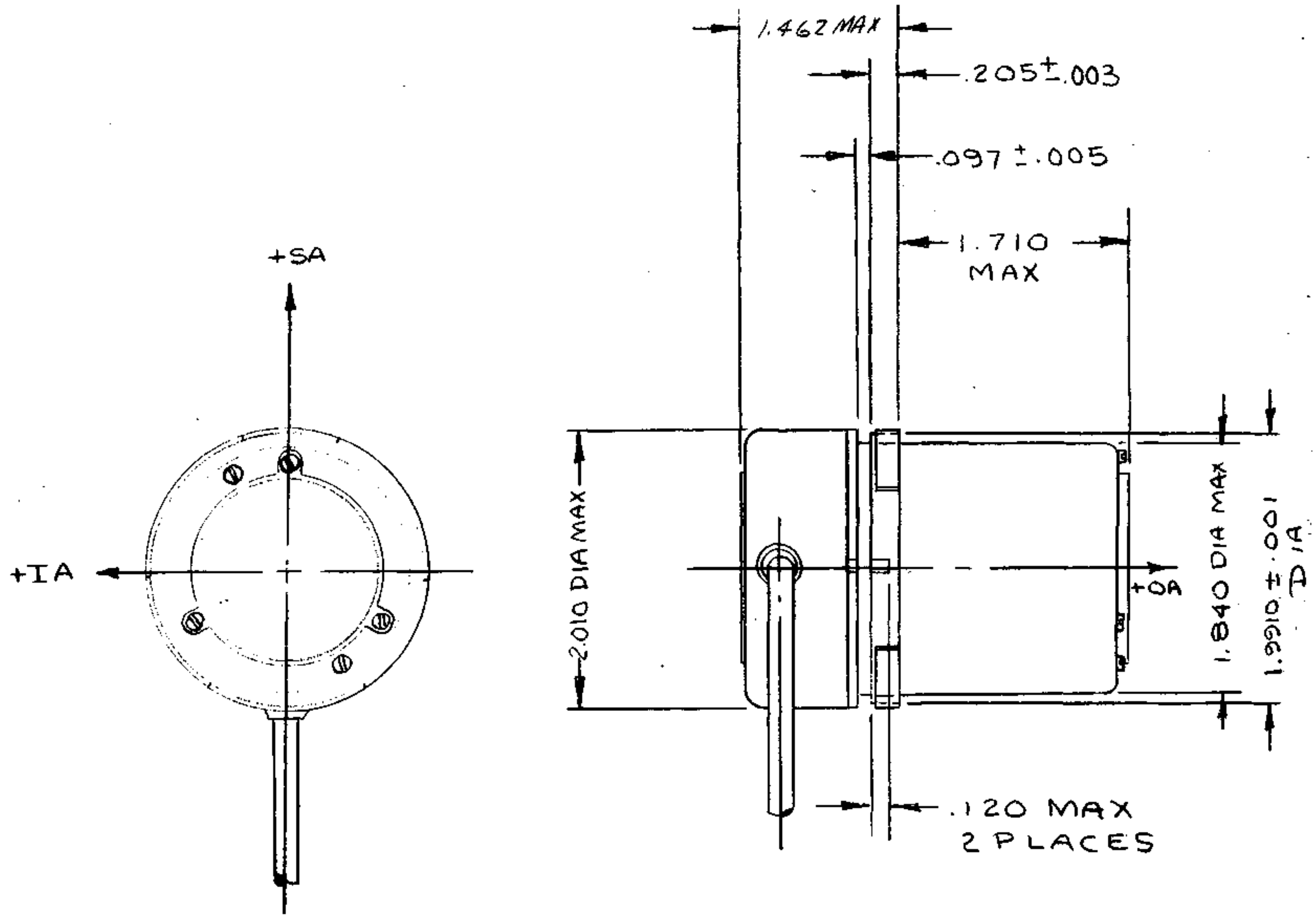

Figure 4. Kearfott Alpha II Gyro, Outline Drawing

3.2.2 Design and Performance Summary. Table 4 summarizes the pertinent electrical and mechanical data for the Kearfott Alpha II gyro. An outline drawing of the gyro is shown in figure 4.

Table 4. Kearfott Alpha II Gyro Characteristics

- Gyro

Weight	approx. 0.85 pound
Overall dimensions	
Length	3.172 in. max
Diameter	
Cable end	2.010 in. max
Bellows end	1.840 in. max
Mounting diameter	1.9910 ±.001 in.
Operating temperature	165±2° F
Transfer function	29.3 ± 24% mv/mr IA
Open loop gain	12.4 ± 19%
Gimbal freedom	±2.4 degrees min
Input angle freedom	0.19 degree
Characteristic time	6.4 ms ± 24%
Warm-up time (from 70° F)	4 minutes max
Gyro noise	0.2°/hr max
Non-acceleration sensitive drift	2.0°/hr max
Acceleration sensitive drift	1.0°/hr/g max. each axis
Anisoelastic drift	
30 to 1500 Hz	$0.02°/hr/g^2$ peak max
30 to 2000 Hz	$0.10°/hr/g^2$ peak max
Random drift (1 sigma value)	0.05°/hr max
Maximum torquing rate	5.0°/sec

- Heating and sensing element

Warmup heater excitation	115 volts, 1 phase, 60 Hz
Warmup heater power	112 watts max
Warmup heater resistance (at 70° F)	132±13 ohms dc
Control heater excitation	28 volts dc
Control heater power	30 watts max

Table 4. Kearfott Alpha II Gyro Characteristics (Cont.)

Control heater resistance (at 70° F)	31.4±3.1 ohms dc
Temperature sensor resistance (at operating temperature)	780 ohms
• <u>Motor and motor-float assembly</u>	
Output axis inertia	117 gm-cm^2 nominal
Motor excitation	27.5 to 29 volts rms single phase square wave at 400 ± 0.04 Hz
Starting power	3.75 watts max
Running power	3.2 watts max
Starting current	0.154 amp max
Running current	0.134 amp max
Angular momentum of wheel	227,000 $\frac{\text{gm-cm}^2}{\text{sec}}$ nominal
• <u>Signal generator</u>	
Excitation	3.5±.07 volts, 1 phase 5000 ± 0.5 Hz
Input current	0.210 amp max
Signal gradient	2.36 to 2.4 mv/mr
Signal linearity	1% of full scale
Null	1.0 mv rms max
Phase angle (secondary to primary)	6.0 ± 3 degrees leading
Input impedance (at 70° F and 5000 Hz)	100 + j 472 ohms ± 10%
Output impedance (at 70° F and 5000 Hz)	58 + j 45 ohms ± 10%
• <u>Torque generator</u>	
Current	150 ma max.
Scale factor	134 ± 13 deg/hr/ma
Linearity	±0.05 percent
Control field resistance (at 70° F)	38 ohms ± 10%
Control field time constant	55 microsec ± 10%

3.2.3 General

A brief description of the major components of the Kearfott Alpha II gyro follows.

3.2.3.1 Motor and Float Assembly. The motor and float assembly is a hermetically sealed unit containing the gyro motor and is the movable inner gimbal of the gyro. The motor and float assembly is located radially and axially within the housing (outer gimbal) by pivots and jeweled bearings. Mounted on the end of the motor and float assembly is the torque generator and signal generator rotor assembly.

Assembled within the float is the synchronous hysteresis motor. The gyro motor consists of a dynamically balanced rotor mounted between precision ball bearings contained within a rigid housing. The rotor incorporates a solid ring of high hysteresis steel which rotates with the three-phase field. With a high inertia-to-weight ratio of the rotor, an angular momentum of 227,000 gm-cm^2/sec is achieved at a synchronous speed of 24,000 rpm.

3.2.3.2 Torque Generator. The torque generator operates on the D'Arsonval principal. Permanent dc magnets and return paths are fixed to the gyro housing while two coils, 180 degrees apart, are attached to the end of the motor-float assembly. In this configuration, all torques applied to the float by the torque generator are in the form of couples with their axis coincident with the precession axis of the gyro.

3.2.3.3 Signal Generator. Utilizing a differential transformer-type signal generator, an a-c output voltage is generated on the signal generator secondary which is proportional to the angular position of the inner gimbal. This type device gives high resolution and linearity. The excitation windings and return path are fixed to the gyro housing while two secondary coils, are mounted on the motor-float assembly. These coils are located in the same assembly on the motor-float as are the torque generator coils.

3.2.3.4 Housing and Heater. The housing is a hermetically sealed case used for supporting the motor-float assembly. It is made of a thick section of aluminum to provide an isothermal environment for the float assembly and damping fluid. The outer surface of the housing contains a flange which is used to mount the gyro. Glass-insulated terminals are provided in the housing assembly to permit electric leads to the motor, torque generator and signal generator secondary. Balance adjuster parts are also located in the housing to permit trim of the mass unbalance of the motor-float assembly when the instrument is calibrated after final assembly. Located about the gyro housing is the heater sensor element. This element contains a warm-up heater, an operate heater and a temperature sensing element. Covering the housing are shields of high permeability, with low strain sensitivity characteristics. These shields provide magnetic shielding for the gyro's sensitive elements.

3.2.3.5 Damping Fluid. The gap between the motor-float assembly and the gyro housing is filled with a polychlorotrifluoroethylene type oil. The density of this fluid is the same as that of the motor-float assembly. Thus supported, the motor-float assembly is essentially free of all friction. The fluid viscosity provides viscous damping to the float by laminar shear.

3.2.3.6 Bellows. A bellows (located at one end of the case) compensates for the change in fluid volume due to heating and cooling.

3.2.4 Special Features. A few of the more important design features of the Kearfott Alpha II gyro are listed below.

3.2.4.1 Motor. The use of a special high density inertia ring and low density beryllium endbells has resulted in a high angular momentum-to-weight ratio. As drift stability is proportional to wheel angular momentum, the result has been a gyro with much greater drift stability than units of comparable size and weight but with lower wheel angular momentum.

3.2.4.2 Float Assembly. All sealing of the float assembly is accomplished by solder joints to eliminate any possibility of fluid leakage into the float. Cements are not used to join any critical parts together. Tests have proven that these solder joints are immune to long term effects of temperature and immersion in damping fluid.

3.2.4.3 Torquer and Signal Generator. The signal generator stators and torque generator magnets are external to the gyro main housing. Besides the obvious advantage of eliminating a major source of bubbles and contamination from foreign particles in the gyro fluid, this design also has the important advantage of eliminating complete teardown as a result of problems with the magnets or signal generator stators by allowing them to be replaced or adjusted without gyro teardown.

3.2.4.4 Damping Fluid. A proven polychlorotrifluorethylene oil is used as damping fluid. This fluid has been proven by Kearfott to have no separation problems that result in acceleration-sensitive drift changes.

3.2.4.5 Trim of Acceleration Sensitive Drift. By means of an externally adjustable balancing arrangement, the acceleration-sensitive drift components may be trimmed to a low level. This balancing arrangement combines fine sensitivity with positive stability and permits final trim of the acceleration-sensitive drift component to be performed under operating conditions, thus assuring low drift levels.

3.2.4.6 Flexleads. Silver-copper alloy flexleads are formed and annealed to the operating configuration prior to assembly into the instrument. This processing of the flexleads reduces the possibility of a shift in fixed restraints should the gyro be stored with the gimbal in an off-null position.

3.3 Bench Test Equipment Description

3.3.1 Summary. The bench test equipment (BTE) for the RMP has the basic function of simulating the Nimbus spacecraft interface, and providing means for performing functional and, to some extent, diagnostic tests on the RMP. The test capability provided by the BTE includes the following:

- Telemetry channel verification and calibration
- Command function verification

- Scale factor and bias measurement
- Noise level measurement
- Power level measurement
- RMP scale factor and bias measurement
- Gyro-loop transient performance
- Threshold and hysteresis tests.

The BTE is used, in conjunction with auxiliary equipment, to perform factory acceptance tests (FAT) and qualification tests on RMP units prior to delivery. It is also used at the spacecraft integration facility to perform bench acceptance tests on delivered units.

The physical equipment consists of an electronic console with attending cable, a test table, and an RMP holding fixture and a self-test plug.

Test points for use by the BTE are provided in connector J4. No connections are made to J4 by the spacecraft harness. In addition, terminals J1-15, -16 and -35 are intended primarily for the BTE.

In this section a description of the capabilities of the Nimbus RMP bench test equipment, Sperry Part No. 4310-90535 is provided. This section is divided into the following sub-sections; mechanical features, electrical specifications, and controls and terminations of the BTE. The BTE is described, in detail, in the BTE Instruction Manual Sperry Publication No. CA31-0011, dated November 1967.

3.3.2 Mechanical Features

3.3.2.1 General. The BTE consists of the following major units:

Unit	Sperry Part Number
Test console	4310-90535
Interconnecting cable	4310-80218
Test table	4310-90536
Holding fixture (Nimbus B)	4310-90527
Holding fixture (Nimbus D)	4310-90772
Self-test plug	4310-10269

3.3.2.2 Test Console. The test console, houses all the electrical components and circuitry. It consists of a standard Emcor frame housing the following removeable assemblies:

Item	Part Number
Control panel	4310-65318
A-C voltmeter	Triolab Model 109-1
D-C voltmeter	Triolab Model 310-2
D-C power supply	Kepco PRM 24-5

The cabinet measures 24 inches wide, 24 inches deep and 62 inches high.

The control panel provides all the power, control and monitoring interconnections to the RMP and contains most of the circuitry associated with these functions. It consists of a 1/8-inch aluminum panel to which is attached a 17- by 12- by 3-inch steel chassis. The five plug-in assemblies associated with the control panel are:

Assembly	Receptacle	Part Number
Clock counter card	J48	4310-65272
Clock output card	J49	4310-65273
Bias supply card	J50	4310-65319
Relay K3	J53	P&B PW5LS
40-kHz oscillator	J52	Robinson-Halpern FS4002

The console is equipped with four heavy duty casters. The full-length rear door can be locked. The drawer at the bottom of the console provides storage for the interconnecting cable, self-test plug, and holding fixtures. Two 60-Hz power strips, with ample outlets for low-power auxiliary equipment, are located in the rear of the console.

3.3.2.3 Test Stand. The test stand consists of a commercial, cast-iron surface plate resting on a four-legged base via three leveling adjustments. Mounting blocks, attached to the face of the surface plate, permit an RMP in its holding fixture to be mounted on the test stand in a number of attitudes. The test stand is used at the spacecraft integration facility for bench acceptance testing of newly delivered RMP units and for possible diagnostic testing. The overall test stand weighs about 300 pounds.

3.3.2.4 Holding Fixtures. The holding fixture for the Nimbus B RMP is a square, magnesium ring with a 6- by 6-inch opening to receive the RMP. The RMP is secured to the fixture with six 8-32 machine screws. The fixture, in turn, is attached to the test stand using three or four 1/2-13 bolts. The Nimbus D RMP holding fixture is a solid, square, 1/2-inch thick aluminum plate with twelve 8-32 tapped holes for securing the RMP. It mounts on the test stand in the same manner as the Nimbus B fixture.

During factory acceptance testing at Sperry, the RMP is mounted on a precision, two-axis test table, using the holding fixtures described in the previous paragraph.

3.3.2.5 Interconnecting Cable. The RMP-to-BTE interconnecting cable is 10 feet long terminated at the BTE end by a single, 75-pin, Winchester XAC, screwlock connector. The RMP end terminates in four Cannon D-type connectors. When testing a Nimbus B RMP, the P3 plug remains unconnected since there is no mating receptacle in that unit.

3.3.2.6 Self-Test Plug. The self-test plug is a 75-pin, Winchester XAC connector with a circuit board contained within the metal hood. The self-test plug is inserted into J47 on the control panel in place of the interconnecting cable.

3.3.3 Electrical Specifications

3.3.3.1 60-Hz Power Input. The BTE test console requires a single-phase input from a 3-prong, 60-Hz receptacle as follows:

115 ±15 vac at 150 watts* max.

Line voltage changes, in excess of 5 volts from the value at which the test console was calibrated, may necessitate recalibration, as determined by self-test procedure.

3.3.3.2 D-C Outputs. The BTE test console provides the following RMP dc excitations:

Function	DC Voltage	Max. Load Current	Terminal
Inverter power	-26.0 ±1.0	1 amp	J47-37
Relay (heater) power	-26.0 ±1.0	2 amps	J47-40
Telemetry power	-26.0 ±1.0	10 ma	J47-25
Gyro bias	-10.0 ±0.5	2 ma	J47-16
Gyro bias	+10.0 ±0.5	2 ma	J47-17
Rate test bias	N/A	±10 ma	J47-64

3.3.3.3 Clock Outputs. The BTE test console provides five, square-wave, clock outputs with the following characteristics:

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*Exclusive of any auxiliary equipment

Frequency	No-Load Voltage Swing	Min. Load Impedance (ohms)	Terminal
5 kHz	-0.10 ±0.05 to -5.4 ±0.3	0	J47-58
400 Hz, ϕA	-1.5 ±1.0 to -24.5 ±1.5	2000	J47-12
400 Hz, ϕB	-1.5 ±1.0 to -24.5 ±1.5	2000	J47-18
400 Hz, ϕA	-0.3 ±0.2 to -5.7 ±0.3	0	J47-10
400 Hz, ϕB	-0.3 ±0.2 to -5.7 ±0.3	0	J47-14

All clock outputs are phase-locked with respect to each other, and 400-Hz, phase B outputs lead phase A outputs by 90 ±2 degrees. The low-level, 400-Hz outputs on terminals 10 and 14 are not used by present RMP units.

3.3.3.4 Command Outputs. The BTE test console provides six command channels with the following characteristics:

Pulse Width	Pulse Amplitude	Switch Position Command Selector	Terminal
70 ±5 msec	0 to -26 ±1 volts	1	J47-38
70 ±5 msec	0 to -26 ±1 volts	2	J47-26
70 ±5 msec	0 to -26 ±1 volts	3	J47-50
70 ±5 msec	0 to -26 ±1 volts	4	J47-22
70 ±5 msec	0 to -26 ±1 volts	5	J47-34
70 ±5 msec	0 to -26 ±1 volts	6	J47-62

In addition, the UMBILICAL switch, S4, when depressed, impresses -26 vdc on terminal J47-8. The AGE-OFF switch, S13, when depressed, impresses -26 vdc on terminal J47-76 through a 75-ohm series resistor.

The command output on terminal J47-62 (position 6) is not used by present RMP units.

3.3.3.5 A-C Monitor. The Triolab Model 109-1 voltmeter, used in the a-c monitor circuit, has the following characteristics:

Voltage ranges	-	1 mv to 300 volts full scale in 12 ranges
Input impedance	-	10 megohms, shunted by 100 pf
Frequency range	-	20 to 80,000 Hz
Accuracy	-	±2 percent of full scale

C

The A-C MONITOR switch, S11, has twelve positions, six of which are connected to the RMP interface as follows:

Switch Position	Terminal
4	J47-66
5	J47-82
6	J47-78
7	J47-60
8	J47-59
9	J47-57

Front panel jacks, J1 (high) and J2 (low), are permanently connected to the meter input.

3.3.3.6 D-C Monitor. The Triolab Model 310-2 voltmeter, used in the dc monitor circuit, has the following characteristics:

Voltage ranges	-	60 mv to 200 vdc full scale in 12 ranges
Input impedance	-	10 megohms, minimum
Accuracy	-	±0.5 percent of full scale, except ±1 percent on 60-mv scale

The D-C MONITOR switch, S8, has twelve positions, five of which connect to the RMP interface as follows:

Switch Position	Terminal
7	J47-52
8	J47-71
9	J47-77
10	J47-63
11	J47-80

3.3.3.7 Telemetry Monitor. The TELEMETRY OUTPUT meter and associated amplifier have the following characteristics:

Voltage range	-	0 to -8 vdc
Input impedance	-	5 megohms connected to a -8 vdc source
Accuracy	-	±50 mv dc

The TELEMETRY MONITOR switch, S10, has fourteen positions, thirteen of which connect to the RMP interface as follows:

Switch Position	Terminal
1	J47-23
2	J47-29
3	J47-35
4	J47-27
5	J47-41
6	J47-47
7	J47-33
8	J47-39
9	J47-53
10	J47-45
11	J47-51
12	J47-48
13	J47-24

3.3.3.8 Current Monitor. The RMP input current monitor resistor, available across jacks J10 to J9, has a value of 0.90 ohms ±5 percent, when the CURRENT MONITOR switch, S12, is ON. The resistor is shorted when the CURRENT MONITOR switch is OFF.

3.3.4 Controls and Terminations

3.3.4.1 Control Functions. A functional description of each of the controls on the BTE control panel follows.

Designation	Position	Function
A-C MONITOR	1	5-kHz clock
	2	400-Hz clock, phase B
	3	400-Hz clock, phase A
	4	Gyro signal generator output
	5	Gyro signal generator excitation
	6	Motor voltage
	7	Motor current
	8	Heater controller preamp output
	9	Gyro preamp output

Designation	Position	Function
	10	N/C
	11	N/C
	OFF	N/C
TELEMETRY MONITOR -	1	Relay status No. 1 T/M (telemetry)
	2	Relay status No. 2 T/M
	3	Primary voltage T/M
	4	Motor voltage T/M
	5	Motor current T/M
	6	Gyro sync T/M
	7	Heater power T/M
	8	Gyro temperature T/M
	9	RMP temperature T/M
	10	Indicated rate T/M, high resolution
	11	Indicated rate T/M, medium resolution
	12	Indicated rate T/M, low resolution
	13	Spare
	OFF	N/C
D-C MONITOR	1	RMP input voltage (CURRENT MONITOR - OFF)
	1	RMP input current (CURRENT MONITOR - ON)
	2	-10 vdc gyro bias supply
	3	+10 vdc gyro bias supply
	4	+3 vdc clock supply
	5	+5.1 vdc rate test supply
	6	RATE TEST AMPLITUDE potentiometer output
	7	RMP rate loop output
	8	-12 vdc RMP supply T.P. (test point)
	9	+12 vdc RMP supply T.P.
	10	Primary voltage T.P.
	11	Heater voltage T.P.
	OFF	N/C

Designation	Position	Function	
		Sperry Gyro	Kearfott Gyro
COMMAND SELECTOR	1	RMP OFF	RMP OFF
	2	RMP ON	RMP ON
	3	Launch mode	Lower motor voltage
	4	Heater ON	Heater OFF
	5	Orbit start	Motor ON
	6	Spare	Spare
COMMAND PULSE		Initiates command pulse to channel designated on the COMMAND SELECTOR switch.	
RMP INPUT - ON Pos.		Enables -26 vdc to relay interlock circuit. Subsequent transmission of RMP OFF command enables -26 vdc to RMP input terminals.	
RMP INPUT - OFF Pos.		Removes -26 vdc from RMP input and relay interlock circuit.	
RMP ON (lamp)		Indicates relay K1 in RMP is in latched state.	
RMP INPUT - ON (lamp)		Indicates -26 vdc is enabled to RMP input terminals. If, and only if, both the RMP ON and the RMP INPUT-ON lamps are lighted, then the RMP is energized.	
RMP INPUT - OFF (lamp)		Indicates BTE -26 vdc supply is on, but is not enabled to the RMP input.	
60-Hz POWER		Turns on 60-Hz power to BTE and power strips in rear on console. Energizes all BTE power supplies and meters.	
UMBILICAL		Energizes relay K3 in RMP. Required for all starts of RMP units containing Sperry gas bearing gyro.	
AGE-OFF		Resets relays in RMP to RMP OFF mode. Exactly duplicates action of RMP OFF command.	

Designation	Function	
CURRENT MONITOR - ON Pos.	Enables measurement of RMP input current on position 1 of the D-C MONITOR. Permits measurement of RMP input current at jacks J10 to J9.	
CURRENT MONITOR - OFF Pos	Enables measurement of RMP input voltage on position 1 of the D-C MONITOR. Shorts current sampling resistor across jacks J10 to J9.	
RATE TEST MODE (-) Pos.	Rate test current summation produces negative change in rate loop output.	
RATE TEST MODE (+) Pos.	Rate test current summation produces positive change in rate loop output.	
RATE TEST MODE OFF Pos.	Disconnects rate test current supply from gyro rate loop.	
RATE TEST AMPLITUDE - Pos. 1	Fixed test current	10 ma
2	Fixed test current	7.5 ma
3	Fixed test current	5.0 ma
4	Fixed test current	2.5 ma
5	Variable test current	1 ma/volt
6	Variable test current	0.1 ma/volt
7	Variable test current	10 microamp/ volt
8	Variable test current	1 microamp/ volt
OFF	Zero test current	
RATE TEST AMPLITUDE	Provides variable rate test current when the RATE TEST AMPLITUDE switch is set to positions 5, 6, 7, or 8, with scaling as indicated. Potentiometer output voltage is indicated at position 6 on the D-C MONITOR	

Designation	Function
RATE LOOP MODE - NIM D	Connects positions 2 and 3 of the A-C MONITOR to low-level, 400-Hz clock outputs.
RATE LOOP MODE - NIM B	Connects positions 2 and 3 of the A-C MONITOR to the high-level, 400-Hz clock outputs.
RATE LOOP MODE - OPEN LOOP	Same as NIM B position; plus shorts output of rate loop amplifier in the RMP.

3.3.4.2 Jack and Receptacle Functions. Table 5 lists all GR plug jacks and other receptacles and designates the function of each. The jacks are provided to permit auxiliary monitoring equipment to be connected to the BTE test console during RMP testing. For instance, during RMP qualification testing, it is necessary to simultaneously record a number of the telemetry outputs. All jacks are permanently connected to the functions indicated independent of switch positions, except that J10 is shorted to J9 when the CURRENT MONITOR switch is OFF.

3.3.4.3 Terminal Strip Functions. The function assigned to each external terminal strip location is listed below:

Location	Function
TB1-1	26 vdc power supply input (+)
TB1-2	26 vdc power supply input (-)
TB1-3	N/C
TB1-4	Jumper to TB1-5
TB1-5	Auxiliary power supply (-), or jumper to TB1-4
TB1-6	Auxiliary power supply (+)
TB3-1	60-Hz power input
TB3-2	60-Hz power input
TB3-3	House ground; jumper to TB3-4
TB3-4	Power strip ground; jumper to TB3-3
TB3-5	60-Hz power output to power strips
TB3-6	60-Hz power output to power strips
TB4-1	D-C meter input (+)
TB4-2	D-C meter input (-)
TB4-3	Shield ground

Designation	Function
TB4-4	A-C meter input, high
TB4-5	A-C meter input, low
TB4-6	Shield ground

Table 5. BTE Test Console Jack and Receptacle Functions

Designation	Color	Function
J1	Red	AC meter Hi
J2	Blk	AC meter Lo
J3	Red	DC meter +
J4	Blk	DC meter -
J5	Red	Gyro torquer T.P.
J6	Blk	Signal ground -1
J7	Red	Command pulse
J8	Red	Rate loop output
J9	Blk	Signal ground - 1
J10	Blk	Input current (P.G.)
J11	Red	5-kHz clock
J12	Blk	Signal ground - 1
J13	Red	Heater voltage T.P.
J14	Red	Heater controller demodulator T.P.
J15	Red	Heater common
J16	Red	Heater controller preamplifier T.P.
J17	Red	Gyro pickoff excitation T.P.
J18	Blk	Signal ground - 2
J19	Red	Primary voltage T.P.
J20	Red	Gyro pickoff output T.P.
J21	Blk	Signal ground - 2
J22	Red	Gyro preamplifier output T.P.
J23	Red	+12 vdc T.P.
J24	Blk	Signal ground - 2
J25	Red	-12 vdc T.P.
J26	Red	Motor current T.P.
J27	Blk	T/M ground
J28	Red	Motor voltage T.P.
J29	Red	Motor voltage T/M
J30	Blk	T/M ground
J31	Red	Relay status T/M No. 1
J32	Red	Motor current T/M
J33	Blk	T/M ground
J34	Red	Relay status T/M No. 2
J35	Red	Gyro sync T/M
J36	Blk	T/M ground
J37	Red	Primary voltage T/M
J38	Red	Gyro tempera-ture T/M
J39	Blk	T/M ground
J40	Red	Package Temperature T/M

Table 5. BTE Test Console Jack and Receptacle Functions (Cont.)

Designation	Color	Function
J41	Red	Heater power T/M
J42	Blk	T/M ground
J43	Red	Rate T/M - medium resolution
J44	Red	Rate T/M - high resolution
J45	Blk	T/M ground
J46	Red	Rate T/M - low resolution
J47		RMP/BTE connector
J48		Clock counter card
J49		Clock output card
J50		Bias supply card
J52		Oscillator
J53		Relay K3

4.0 DELIVERABLE ITEMS

The Nimbus D RMP program, Contract NAS 5-10391, had been modified to either delete or add workscope. All gyros were supplied to this program as Government Furnished Equipment (GFE). A list of contractually deliverable items is given below. All items have been delivered and accepted by NASA/GSFC. DD 250 documents exist for each of the items as listed.

Contract Item	Description	DD 250
1	Prototype RMP S/N 5	2/16/68 - 12069
2	Flight RMP S/N 6	8/19/69 - 29206
3	Bench Test Equipment S/N 3	6/16/67 - 2690
4	Flight RMP S/N 7	2/7/69 - 24024
5	Spares 6 pc boards	4/22/71 - 2613
	RMP Instruction Manual	4/16/70 - 35846
	BTE Instruction Manual	6/16/67 - 2690
	Final Engineering Report	

5.0 PROGRAM ACCOMPLISHMENTS

5.1 Background. This section presents technical milestones achieved under this contract. Emphasis is placed on the work associated with development of an advanced Long Life Rate Measuring Package including integration of the Kearfott ball bearing gyro. A description of the bench test equipment fabricated under this contract is also included.

5.2 Summary

5.2.1 Procurement and Fabrication. Following procedures established in the Nimbus B RMP program, electrical subassemblies were purchased from Spaco, Inc. of Huntsville, Alabama, and later from Twintech Electronics of Fayetteville, Tennessee (a company established by former Spaco personnel when Spaco stopped manufacturing printed circuit assemblies).

Electrical components (either ER types or those screened by Sperry) were supplied to the vendor along with wire, certain critical hardware items, and the artwork masters and assembly drawing for the printed circuit cards. The vendor performed all assembly operations and continuity and resistance checks. After passing inspection by a DCAS inspector, the units were shipped to Sperry where they were again inspected, functionally tested, and finally, conformally coated.

A summary of the various subassembly procurements is given below. Note that set S/N 4 was purchased as part of the Nimbus B RMP program. In addition, a summary of the parts screening program at Sperry is included in Appendix II.

5.2.2 Gyro Procurement. Four Kearfott Alpha II gyros were purchased on the Nimbus B RMP program and then "GFE'd" to the Nimbus D program. The gyros (S/N 1 through S/N 4) were purchased to Sperry drawing 1200941 and purchase specification P1581854 included in Appendix I. (See section 3.2 for a technical discussion of the gyro.)

An additional Alpha II gyro (S/N R-87) was "GFE'd" to Sperry for use in the engineering model RMP EM01. This gyro had been purchased for the RAGS program several years previously.

Table 6 summarizes the Kearfott final test data on the four purchased gyros. Upon delivery to Sperry, each of the gyros was subjected to a factory acceptance test and then installed in one of the RMP's. Gyros S/N 1, 3, and 4 were ultimately delivered in RMP's to NASA. Gyro S/N 2 experienced a float stiction malfunction during RMP final acceptance test and was returned to Kearfott for rebuild as S/N 2A.

Subassembly Procurement Summary

S/N	M.I. Date	Del'y Date	Vendor	Comments
4	9/1/66	12/27/66	Spaco	Complete Gas Bearing Set
5 and 6	6/20/67	11/17/67	Spaco	Complete Gas Bearing Set
5 and 6	7/11/67	11/17/67	Spaco	Ball Bearing Relay Cards Only
7	3/7/68	6/18/68	Spaco	Complete Ball Bearing Set
6A	2/6/69	6/17/69	Twintech	Ball Bearing P/C Cards Only. Harness, Inverter, and RFI Assembly Fabricated at Sperry

A complete set of sub-assemblies included the following items:

Nomenclature	Part No.
Rate Loop Electronics Card	4216-67676
Power Conditioning Card	4216-67677
Heater Controller Card	4216-67678
Telemetry Signal Conditioning Card	4216-67679
Relay Card A	4216-67680 (Gas Bearing) or 4310-90848 (Ball Bearing)
Relay Card B	4216-67681 (Gas Bearing) or 4310-90841 (Ball Bearing)
Inverter Subassembly	4310-90633
RMP Cable Harness	4216-90956
RFI Assembly	4310-90627

Below is a summary of the wheel operating hours for each of the four gyros for each level of test.

Gyro Serial No.	1	2	3	4	2A
Kearfott test	465	500	621	615	517
Sperry gyro test	187	~200	392	208	206
Sperry RMP test	485	~350	919	340	-
Total hours at delivery	1137	-	1932	1163	-

All of the gyros ultimately malfunctioned, most with only a few thousand hours of operation. The longest-lived unit was gyro S/N 4 which survived one year in orbit aboard Nimbus 4, with just under 10,000 hours of total wheel operation when rotation apparently ceased. The first indications of bearing deterioration were noted with about 6200 hours of accumulated wheel operation. Table 7 briefly summarizes the history of the four purchased gyros.

A second RAGS gyro, S/N R-6, was "GFE'd" to Sperry late in the program to replace gyro S/N R-87, in the engineering model RMP, EM01. Gyro S/N R-87 was used to replace gyro S/N 1 which had experienced bearing degradation in the prototype RMP, PR02, while at General Electric.

5.2.3 Final Assembly and Test. After the subassemblies and gyros had passed individual functional and acceptance tests, they were installed in the RMP's and factory acceptance tests were started. Table 8 summarizes the utilization of each of the subassemblies and gyros.

Factory acceptance tests were conducted in Sperry's gyro evaluation lab which is an environmentally controlled facility with multiple test stations located on concrete pedestals, anchored in virgin soil, free from the building structure. A list of the equipment utilized in these tests is given in the factory acceptance test procedure, T4310-10678.

Vibration testing was conducted at Goddard Space Flight Center, while the thermal-vacuum testing was, in general, conducted at Sperry's environmental laboratory.

The test program experienced relatively few problems. This is a result of the conservative electrical and mechanical design of the RMP. Only four malfunctions occurred in the two flight units while undergoing testing at Sperry and one of these was due to gyro float stiction. Table 9 summarizes the malfunction experience on the Nimbus D program.

Table 6. Alpha II Rate Integrating Gyro P/N C70 2564 015
(Compilation of Final Kearfott Test Data)

	SPECIFICATION				
S/N		1	2	3	4
F/N		2036	2037	7301	7302
Date F.T. Completed		10/14/67	11/20/67	2/6/68	2/8/68
Transfer Function-MV/MRIA	29.4±24%	30.43	29.34	29.80	27.96
Positive OA Freedom - DEG	2.4 MIN	3.90	4.07	3.95	3.57
Negative OA Freedom - DEG	2.4 MIN	3.90	3.70	3.73	3.61
SG Null - MV	1.0 MAX	0.48	0.65	0.71	0.66
Characteristic Time - MS	6.4±24%	6.676	6.520	6.536	5.980
Yozzle Test					
OA Up, Sum of Spikes >0.25 DEG/HR-DEG/HR	1.0 MAX	0.37	0	0	0
SA Up, Sum of Spikes >0.25 DEG/HR-DEG/HR	1.0 MAX	0.48	0	0	0
OA Down, Sum of Spikes >0.25 DEG/HR-DEG/HR	1.0 MAX	0.37	0	0	0
Elastic Restraints - DEG/HR	0.3 MAX	0.219	0.024	0.140	0.280
Vacuum Warmup Test					
Sensor Resistance at 160°F - OHMS		774.0	776.9	772.1	773.2
Calc. Time to Reach 160°F - MIN		16.9	17.4	16.9	16.9
Actual Time to Reach 160°F - MIN	Calc.Time ±6	17.0	18.55	14.8	17.2
S.G. Temp at 160°F - DEG F	135°F MIN	140.3	153.0	138.2	151.1
Tumble Test					
MUIA - DEG/HR/G	±1.0 MAX	-.215	+.133	-0.040	-.146
MUSA - DEG/HR/G	±1.0 MAX	+.097	-.295	-0.067	+.078
Restraints - DEG/HR	±2.0 MAX	-.042	-.070	-.722	-.415
Deviation from Smooth Curve-DEG/HR	0.5 MAX	.160	.068	.100	.160
Random Drift					
OAV 1σ - DEG/HR	0.05 MAX	.007	.014	.000	.003
IAV 1σ - DEG/HR	0.05 MAX	.002	.003	.008	.000
Ramp Drift Rate - DEG/HR/HR	0.0015 MAX	.000314	.000218	.000215	.000310

Table 6. Alpha II Rate Integrating Gyro P/N C70 2564 015
(Compilation of Final Kearfott Test Data) (Cont.)

S/N		SPECIFICATION	1	2	3	4
Drift Tests						
Cycle A						
TSF	- DEG/HR/MA	134 ± 13	131.4	136.1	131.0	141.9
Restraints	- DEG/HR	±2.0 MAX	-.032	-.011	-.730	-.405
MUIA	- DEG/HR/G	±1.0 MAX	-.263	+.105	-.098	-.078
MUSA	- DEG/HR/G	±1.0 MAX	+.014	+.338	+.036	-.037
Cycle B						
TSF	- DEG/HR/MA	134 ± 13	131.3	135.8	130.8	141.9
Restraints	- DEG/HR	±2.0 MAX	-.003	-.020	-.723	-.394
MUIA	- DEG/HR/G	±1.0 MAX	-.250	+.098	-.098	-.135
MUSA	- DEG/HR/G	±1.0 MAX	-.004	+.303	+.029	-.013
Cycle C						
TSF	- DEG/HR/MA	134 ± 13	131.3	136.1	130.8	142.0
Restraints	- DEG/HR	±2.0 MAX	-.055	-.024	-.723	-.419
MUIA	- DEG/HR/G	±1.0 MAX	-.230	+.095	-.095	-.121
MUSA	- DEG/HR/G	±1.0 MAX	-.001	+.259	+.039	-.075
Drift Rate Shifts						
Restraints	Cycle A to B - DEG/HR	0.5 MAX	.029	.009	.007	.011
	A to C - DEG/HR	0.5 MAX	.023	.013	.007	.014
MUSA	Cycle A to B - DEG/HR/G	0.5 MAX	.018	.035	.007	.024
	A to C - DEG/HR/G	0.5 MAX	.015	.079	.003	.038
MUIA	Cycle A to B - DEG/HR/G	0.5 MAX	.013	.007	.000	.057
	A to C - DEG/HR/G	0.5 MAX	.033	.010	.003	.043
Motor Characteristics						
MRDT 30-0 HZ	- SEC (Motor Spec-Ref 40-60 Sec)		56.10	63.00	64.36	52.96
Starting Current	- MA	154. MAX	105	110	95	112
Running Current	- MA	134. MAX	94	95	85	98
Running Power	- WATTS	3.5 MAX	2.28	2.35	2.10	2.25
Rate Mode Output Signal Noise	- DEG/HR	0.4 MAX PEAK TO PEAK	0.174	0.215	0.22	0.36

D

Table 7. Kearfott Gyro Summary

Unit No.	Received by Sperry	Total Operating Hours	Malfunction and Date	Remarks
1	10/22/67	1250	Erratic behavior both gyro drift and wheel run-down - 3/5/69	Erratic behavior verified by Kearfott. Unit disassembled 4/17/69. Results - lubricant breakdown - bearing failure.
2	12/28/67	1050	Hysteresis failure (float stiction) - 5/21/68	Noted during acceptance test at Sperry. Float stiction verified by Kearfott. Unit disassembled.
3	2/14/68	2330	Mass unbalance and low speed run-down out of spec - 2/16/71	"Out-of-spec" verified at Kearfott. Teardown revealed lubricant breakdown.
4	2/14/68	9923	Wheel stalled - 4/8/71	Unit in orbit one (1) year; first indication of malfunction Nov. 1970 (6200 hours).
2A	10/21/69	1152	Yozzle test failure - 3/27/71	Indication of bubble or whisker. Noted during post-vibration test at Sperry. Unit not presently considered flightworthy.

5.3 RMP Accomplishments.

5.3.1 Engineering Unit, EM01, Sperry S/N 4. The Nimbus D engineering model RMP (the fourth unit built by Sperry) was constructed as part of the Nimbus B program. As the "D" castings were not yet available, and since the unit would not experience vibration test, it was constructed using aluminum plates screwed and cemented together. As this was the first unit to employ the Alpha II gyro (S/N R-87), the existing S/N 4 subassembly set had to be modified. This consisted of fabricating the new relay cards and heater controller card using hard-wired,41-pin vector cards, and adding the necessary additional wires to the S/N 4 harness.

Table 8. Gyro and Subassembly Utilization in Nimbus D RMP's

RMP S/N → Sperry S/N →	EM01 S/N 4	PR02 S/N 5	FT03 S/N 6	FT04 S/N 7
Gyro	R-87 - Later replaced by gyro R-6 when gyro R-87 was installed in RMP S/N 5.	S/N 1 - Gyro experienced lubrication failure at G.E. Replaced with gyro R-87 from RMP S/N 4.	S/N 2 - Gyro failed hysteresis during final RMP acceptance test. Replaced with gyro S/N 3.	S/N 4
Subassemblies	S/N 4 - Except heater controller and relay cards were hand wired versions for Kearfott gyro retrofit.	S/N 5	S/N 6 - Later replaced by S/N 6A subassemblies during connector plating change.	S/N 7

Table 9. Malfunction Experience

Date	Unit	Description
8/28/67	RMP EM01, S/N 4	Wire in RMP harness broke during random vibration at GSFC resulting in application of 800 Hz to the spin motor of gyro R-87 causing loss of wheel speed. Examination revealed wire (one added as result of retrofit) had insufficient relief. Wire replaced, and vibration test completed successfully.
4/22/68	RMP FT03, S/N 6	Microcircuit Q402 on the T/M signal conditioning card exhibited abnormal operation during RMP pre-FAT tests. The device was replaced and the failed unit sent to GSFC for failure analysis. The conclusion was that imperfections in the silicon chip may have caused malfunction.
5/21/68	RMP FT03, S/N 6	The RMP failed hysteresis test during final acceptance test due to stiction in gyro S/N 2. Gyro S/N 2 was removed and replaced with gyro S/N 3. Stiction confirmed at Kearfott. Unit torn down and rebuilt as gyro S/N 2A.

Table 9. Malfunction Experience (Cont.)

Date	Unit	Description
1/15/69	RMP FT04, S/N 7	High clock voltage reading during initial FAT of RMP FT04 was caused by open diode CR222 on the power conditioning card. The diode was destroyed during removal so failure mechanism could not be determined. Replaced with new diode.
1/23/69	RMP FT04, S/N 7	Absence of -12 vdc test point output during post-vibration FAT caused by broken lead in harness. Presumed break occurred during vibration due to insufficient slack in lead. An additional length of wire was spliced to lead and resoldered.
3/5/69	RMP PR02, S/N 5	During special tests at G.E., 30-0 Hz run-down test of gyro S/N 1 measured 24 seconds. Gyro had previously exhibited large shifts in output. The gyro was removed on 3/20/69 and replaced by gyro S/N R-87. Teardown of gyro S/N 1 at Kearfott on 4/17/69 revealed lubrication failure of spin bearing.

The unit was successfully tested and delivered to NASA for integration tests. After four months, the unit was returned to Sperry for refurbishment to prototype level so that vibration and thermal-vacuum testing could be performed. The refurbishment consisted of removing the entire S/N 4 subassembly set, including harness, from the original S/N 4 box, and reinstalling them in a regular, machined, Nimbus D RMP casting. In addition, the three hard-wired vector cards had to be ruggedized, a thermal ground plane added to the heater card, and all subassemblies conformally coated. The refurbished unit successfully passed vibration and thermal-vacuum tests, and was redelivered to NASA.

When gyro S/N 1 ultimately failed in RMP PR02, gyro R-87 was removed from EM01, to replace S/N 1 in PR02. A second RAGS gyro, S/N R-6, was "GFE'd" to Sperry for installation in EM01.

Table 10 lists significant milestones in the history of RMP EM01.

5.3.2 Prototype Unit PR02, Sperry S/N 5. The fifth and sixth RMP's fabricated by Sperry originally were to have been the two flight model Nimbus D RMP's, incorporating SYG-4200 gas bearing gyros. With the decision to "fly" the Kearfott Alpha II gyro on Nimbus D, it was required that a qualification unit be fabricated to undergo prototype-level vibration and thermal-vacuum tests, as well as acceleration and humidity tests. Thus, RMP S/N 5 became PR02, rather than FT02.

Table 10. Milestone Summary, RMP EM01

Milestone	Date
Gyro S/N R-87 delivered to Sperry	3/2/67
Gyro S/N R-87 completed gyro test	4/4/67
Pre-FAT of RMP S/N 4 completed	4/10/67
Gyro S/N R-87 installed in RMP S/N 4	4/13/67
Complete acceptance tests at Sperry	4/25/67
Delivery to NASA-GSFC	4/26/67
Integration tests at GSFC	6/26/67
Returned to Sperry for refurbishment to prototype level	8/16/67
Pre-FAT of refurbished RMP S/N 4	8/22/67
Gyro S/N R-87 reinstalled	8/23/67
Complete prototype vibration at GSFC	8/28/67
Complete abbreviated thermal-vacuum at GSFC	8/30/67
Returned to Sperry for special tests in conjunction with RMP PR02; gyro S/N R-87 removed	3/11/69
Gyro S/N R-6 delivered to Sperry	4/4/69
Gyro S/N R-6 completed gyro test	4/8/69
Gyro S/N R-6 installed in RMP S/N 4	4/8/69
Complete acceptance tests at Sperry	4/16/69
RMP S/N 4 delivered to GSFC	4/30/69

The fabrication and test of RMP PR02 was identical to the flight units to follow, with the exception of the more severe environmental test levels and addition of acceleration and humidity tests. All test results before and after all environmental tests were satisfactory. A change in gyro bias of 0.16°/hr was noted after vibration. The origin of the change was thought to be due to the magnetic fields from the shaker. The final bias of the RMP during acceptance test was 0.11°/hr which was acceptable.

Presented below, in summary form, are the results of the tests performed on RMP PR02. Actual performance data is referenced by page to the RMP Log Book.

- Factory Acceptance Test Nimbus D RMP per T/Spec #4310-10678A. Performance data acceptable. See pages 6 through 17 in Log. Test period 12/7/67 to 12/26/67.

- Humidity Test per T/Spec #4310-10841A. Functional data after test acceptable. See pages 17 through 18 in Log. Test period 12/26/67 to 12/27/67.

- Acceleration Test per T/Spec #4310-10677A. Functional data after test acceptable. See page 19 in Log. Test date 12/27/67.

- Factory Acceptance Test per T/Spec #4310-10841A, paragraphs 7.9 through 7.13. Performance data acceptable. See pages 20 and 21 in Log. Test period 12/28/67 to 12/29/67.

- Vibration Testing per T/Spec #4310-10680. Functional data after test indicated a slight change in gyro bias. See pages 21 and 22 in Log. Test date 1/3/68.

- Factory Acceptance Test per T/Spec #4310-10841A, paragraphs 7.9 through 7.13. Performance data indicates an absolute bias of 0.16°/hr, which was a change in bias of 0.16°/hr due to the vibration test sequence. All other performance parameters were acceptable. See pages 23 through 26 in Log. Test period 1/4/68 to 1/8/68. Unit readied for thermal-vacuum tests at GSFC.

- Thermal-Vacuum Test per T/Spec #4310-10679A. Functional data after test indicated a slight change in gyro bias and wheel run down. See pages 26 through 33 in Log. Test period 1/9/68 to 1/22/68. Test conducted at GSFC. An analysis of the heat losses of the RMP during thermal-vacuum tests was made to corroberate the gyro-to-case thermal impedance which controls the total input power to the RMP in orbit. Based on Nimbus B data, it was determined that a nominal gyro-to-case thermal impedance of 14°F/watt was required, such that the input power to the RMP during orbit would be a nominal 8 watts at a spacecraft temperature of 25°C.

The analysis indicated, allowing for the radiation heat loss peculiar to that chamber, the thermal impedance was 12°F/watt. This meant that the RMP total input power in orbit would be 9.3 watts at a spacecraft temperature of 25°C. The analysis is included in Appendix III.

- Factory Acceptance Test per T/Spec #4310-10841A, paragraphs 7.9 through 7.13. Performance data indicated an absolute bias of 0.12°/hr, which is a reduction in the bias witnessed after vibration of 0.04°/hr. This bias level was acceptable. Wheel rundown time reduced slightly but within tolerance. All other performance parameters were acceptable. See pages 34 and 35 in Log. Test period 1/23/68 to 1/24/68.

After successful completion of the final acceptance test at Sperry, RMP PR02 was delivered to G.E. for integration into the prototype Nimbus D ACS.

Several special tests of RMP PR02 were conducted at G.E. with regard to noise problems noted in the prototype ACS. One source of output spikes was caused by physical motion of the ACS induced by rotation of the solar array drives.

In the early part of 1969, RMP PR02 started to display output level shifts up to 0.5 deg/hr and degradation in the 30-0 Hz wheel run down times. The unit was returned to Sperry in March 1969 where the degradation was confirmed. Gyro S/N 1 was removed and returned to Kearfott, where a teardown revealed lubrication failure in one wheel bearing.

Gyro S/N R-87 was removed from RMP EM01, installed in RMP PR02, and returned to G.E.

Table 11 lists significant milestones in the history of PR02, while table 12 lists the wheel run down history of Kearfott gyro S/N 1.

Table 11. Milestone Summary, RMP PR02

Milestone	Date
Gyro S/N 1 delivered to Sperry	10/22/67
Gyro S/N 1 completed gyro test	12/1/67
Pre-FAT of RMP S/N 5 completed	12/7/67
Gyro S/N 1 installed	12/11/67
Complete FAT of RMP S/N 5	12/20/67
Complete humidity and acceleration tests at Sperry	12/27/67
Vibration test of RMP S/N 5 at Sperry	1/3/68
Complete thermal-vacuum tests at GSFC	1/22/68
Complete acceptance test at Sperry	2/15/68
Acceptance test at G.E.	2/23/68
Special tests at G.E.	5/10/68
Special tests at G.E.	10/30/68
Special tests at G.E.	3/5/69
Special tests at Sperry	3/10/69
Remove gyro S/N 1, install gyro R-87	3/20/69
Deliver RMP S/N 5 to G.E.	3/24/69
Special tests at G.E.	5/27/69
Special tests at Sperry	8/12/70

Table 12. Gyro Wheel Rundown Summary, Kearfott Gyro S/N 1

Date	Rundown Times Total	Rundown Times 30-0 Hz	Comments
10/14/67	-	56 sec	Kearfott acceptance data
12/13/67	4m-20 sec	-	Start RMP S/N 5 FAT
12/15/67	4m-35 sec	-	
12/18/67	4m-20 sec	-	
12/20/67	4m-30 sec	-	Complete initial FAT
12/27/67	4m-45 sec	-	Complete humidity test
12/28/67	4m-30 sec	-	
12/29/67	4m-40 sec	-	
1/3/68	4m-12 sec	-	Z-axis vibration
1/3/68	4m-45 sec	-	X-axis vibration
1/3/68	4m-35 sec	-	Y-axis vibration
1/4/68	4m-40 sec	-	
1/8/68	4m-20 sec	-	
1/8/68	4m-12 sec	-	
1/9/68		-	Start thermal-vacuum test
1/22/68	3m-5 sec	-	Complete thermal-vacuum test
1/24/68	3m-42 sec	-	
1/24/68	3m-50 sec	42 sec	Complete final FAT
2/15/68	3m-30 sec	-	Acceptance test at Sperry
2/15/68	3m-23 sec	-	Acceptance test at Sperry (heater off)
2/23/68	3m-11 sec	-	Acceptance test at GE/VFSTC
2/23/68	3m-29 sec	-	Acceptance test at GE/VFSTC
5/10/68	3m-23 sec	36 sec	Special test at GE/VFSTC
10/30/68	3m-53 sec	46 sec	Special test at GE/VFSTC
10/30/68	3m-40 sec	44 sec	Special test at GE/VFSTC
10/30/68	3m-45 sec	49 sec	Special test at GE/VFSTC
3/5/69	2m-38 sec	24 sec	Special tests at GE/VFSTC
3/5/69	2m-28 sec	16 sec	Special tests at GE/VFSTC

Table 12. Gyro Wheel Rundown Summary, Kearfott Gyro S/N 1 (Cont.)

Date	Rundown Times Total	Rundown Times 30-0 Hz	Comments
3/10/69	2m-43 sec	27 sec	Tests at Sperry
3/10/69	2m-41 sec	27 sec	Tests at Sperry
3/11/69	2m-47 sec	27 sec	Tests at Sperry in RMP S/N 4
3/14/69	2m-25 sec	35 sec	Tests at Sperry
3/20/69	-	-	Gyro S/N 1 removed from RMP S/N 5

5.3.3 Flight Unit FT03, Sperry S/N 6. RMP FT03 had a lengthy history starting in April of 1968. The unit was originally assembled with Kearfott gyro S/N 2. Except for a microcircuit malfunction noted during preliminary factory acceptance tests (FAT), the unit satisfactorily completed all FAT and environmental tests. During final acceptance testing on 5/21/68, the unit failed to pass the hysteresis test with an indication of gyro output axis stiction. Gyro S/N 2 was subsequently removed, torn down, and rebuilt as gyro S/N 2A.

Kearfott gyro S/N 3 was installed on 6/21/68 and RMP FT03 satisfactorily completed a repeat of all FAT and environmental tests and was available for final acceptance tests on 7/17/68. A soldering problem (noted at GSFC) voided this package and it was subsequently stripped of its harness and electronics subassemblies, these to be used as spares (RMP S/N 4B).

A new harness and electronic subassemblies (S/N 6A) were fabricated and assembled into the S/N 6 structure bringing about the latest test cycle.

Presented below, in summary form, are the results of the FAT and environmental tests performed on RMP FT03 (S/N 6).

All environmental and FAT tests with Kearfott gyro S/N 2 were satisfactory. The test period was 5/2/68 to 5/17/68. The gyro failed on 5/21/68 in final acceptance test. See pages 1 through 44 in Log #1.

- Factory Acceptance Test Nimbus D RMP per T/Spec #4310-10678A. Gyro S/N 2 removed from RMP for malfunction analysis on 5/22/68. Gyro S/N 3 installed and factory acceptance test resumed on 6/24/68. Performance data acceptable. Performance data indicated an absolute bias of 0.066°/hr. See pages 44 (Log #1) to 1 (Log #2). Test period 6/24/68 to 6/27/68. Unit readied for vibration test at GSFC.

- Vibration Testing per T/Spec #4310-10680. Functional data after tests acceptable. Slight temporary changes in bias and wheel rundown were detected during tests. See pages 2 and 3 in Log #2. Vibration input curves retained at GSFC. Test date 7/1/68.

- Factory Acceptance per T/Spec #4310-10841A, paragraphs 7.7 through 7.13, 7.15, and 7.17. Performance data acceptable. Performance data indicated an absolute bias of 0.086°/hr which was a change of 0.02°/hr during the vibration test sequence. See pages 4 through 6 in Log #2. Test period 7/2/68 to 7/3/68.
- Thermal Vacuum Test per T/Spec #4310-10679A. Functional data after test acceptable. See pages 6 through 15 in Log #2. Test period 7/3/68 to 7/14/68.
- Factory Acceptance Test per T/Spec #4310-10841A, paragraphs 7.7 through 7.13, 7.15, and 7.17. Performance data acceptable. Performance data indicated an absolute bias of 0.058°/hr which was a change of 0.03°/hr during the thermal vacuum test sequence. Rundown time varied slightly but within tolerance. See pages 16 through 19 in Log #2. Test period 7/15/68 to 7/17/68.

Following the refurbishment of RMP FT03 with the S/N 6A subassemblies, the following test summary was recorded.

- FAT commenced on 6/26/69 and was completed 7/1/69 (Log #2, pages 29 through 38). All test results were satisfactory with no anomalies noted. Of particular interest is the fact that no gyro bias trim adjustment was required, after a full year of storage. The bias of 7/17/68 (Log #2, page 18) was +1.65 mv. The bias on 6/27/69 (Log #2, page 32) was +3.18 mv, a change of only 1.53 mv, or 0.053 deg/hr.
- Vibration tests were conducted at GSFC on 7/15/69 (Log #2, pages 39 through 42). The gyro simulator was substituted for Kearfott gyro S/N 3 during the X-and Y-axes sine and random runs and the Z-axis sine run. Gyro S/N 3 was reinstalled for the Z-axis random run. This was done to avoid excessive accumulated vibration time on gyro S/N 3 which had experienced a complete flight level vibration test on 7/1/68. The test was satisfactory.
- Post-vibration FAT was conducted on 7/16/69 to 7/17/69 (Log #2, pages 42 to 45). The raw bias value was +3.10 mv, a decrease of 0.08 mv, or 0.003 deg/hr from the value prior to vibration.
- Thermal-vacuum testing of RMS S/N 6 commenced on 7/18/69 and was completed on 8/5/69 (Log #2, page 45 to Log #3, page 4). The test was conducted in one of the small, vertical chambers at GSFC. Vibration inputs to this chamber were quite high, making the output recording of rather poor quality. A simple R-C filter was employed at the Brush recorder input to reduce the noise band on the output trace. Several BTE shut-downs occurred as a result of mementary power interruptions at the T & E building, but overall results were satisfactory.
- Post T-V FAT was conducted from 8/6/69 to 8/11/69 (Log #3, pages 5 through 9). The final raw bias value was +3.32 mv, an increase of 0.14 mv, or 0.005 deg/hr from the original value on 6/27/69. Correcting for the BTE error, this represents a final true bias of +1.41 mv, or +0.049 deg/hr.

Table 13 lists all the gyro S/N 3 rundown times obtained during RMP FT03 test including those conducted in 1968. There did not appear to be any degradation in the times listed.

Total gyro operating time as of 8/11/69 was 1305 hours, not including time accumulated at Kearfott prior to delivery to Sperry.

Stability runs of this unit in a spin-axis horizontal, output-axis parallel to earth's axis attitude typically showed occasional unidirectional output transients of 0.2 deg/hr and 30-second duration. Since the transients did not occur in the 0A vertical attitude, they were believed to be due to temporary shifts in the wheel position along the spin axis. The magnitude of the transient was well within both Kearfott and Sperry performance specifications for this gyro, and should not have caused problems to the ACS. This behavior was noted in other gyros on the Nimbus D RMP program and was not considered abnormal for a ball-bearing type gyro.

As this gyro had an unusual amount of operating time before final delivery, it was of interest to plot the mass balance coefficients of the gyro as a function of wheel operating time. The results (figure 5), showed a change in the character of MUSA after the 800-hour point.

Table 14 lists significant milestones in the long history of RMP FT03.

<u>5.3.4 Flight Unit FT04, Sperry S/N 7.</u> RMP FT04 was the last unit fabricated on the Nimbus D RMP program. Because of the timing of the solder problem experienced at GSFC which allowed the appropriate changes to be incorporated in the original build of this unit, RMP FT04 was delivered ahead of FT03 and became the unit to actually "fly" on Nimbus 4.

Rather than describe here the effort involved in making the connector changes to FT03 and FT04, the program plan for these tasks is reproduced in Appendix VI.

Fabrication and test of RMP FT04 were normal with the exception of two minor malfunctions. As one of these involved a broken harness lead during vibration, the documentation covering the occurrence and repair are included in Appendix VII.

Presented below (in summary form) are the results of the tests performed on RMP FT04. Actual performance data is referenced by page to the RMP Log book.

- FAT per #4310-10678C Testing Began on 1/15/69. Noted out-of-tolerance readings on 1/15/69 (page 8, Log book). Analysis of low gyro temperature conditions indicated incorrect resistor on gyro normalization assembly. Resistor replaced on 1/16/69. Analysis of out-of-tolerance reading on 400-Hz, phase A clock input (page 9 of Log book) indicated a diode failure on the power conditioning card. The diode was replaced on 1/17/69. Testing resumed on 1/18/69. Performance data acceptable and indicated on absolute bias of 0.013°/hr. See pages 5 through 21 in Log book. Test completed 1/22/69.

Table 13. Gyro Wheel Rundown Summary, Kearfott Gyro S/N 3

Date	Total	30-0 Hz	Test
2/6/68	-	64.4 sec	Kearfott Test*
6/24/68	5m-10 sec	47 sec	FAT
6/26/68	5m-00 sec	52 sec	FAT
6/26/68	4m-57 sec	-	FAT
6/27/68	4m-58 sec	48 sec	FAT
7/1/68	4m-46 sec	-	Vibration at GSFC
7/1/68	4m-25 sec	-	Vibration at GSFC
7/1/68	4m-20 sec	-	Vibration at GSFC
7/2/68	4m-57 sec	51 sec	ReFAT after vibration
7/3/68	4m-58 sec	-	
7/3/68	4m-52 sec	-	T-V at Sperry
7/14/68	4m-55 sec	-	End T-V
7/16/68	5m-05 sec	55 sec	ReFAT after T-V
7/17/68	4m-30 sec	66.5 sec	ReFAT after T-V
6/26/69	5m-35 sec	59 sec	FAT
6/27/69	4m-16 sec	55 sec	FAT
7/1/69	5m-25 sec	56.7 sec	FAT
7/15/69	4m-40 sec	-	Vibration at GSFC
7/16/69	4m-57 sec	50 sec	ReFAT after vibration
7/17/69	5m-10 sec	55 sec	ReFAT after vibration
7/18/69	5m-15 sec	-	T-V at GSFC
8/5/69	4m-45 sec	-	End T-V
8/7/69	5m-00 sec	54 sec	ReFAT after T-V
8/11/69	5m-05 sec	46 sec	ReFAT after T-V
11/5/69	5m-01 sec	-	Acceptance at GSFC
11/5/69	5m-25 sec	54 sec	Acceptance at GSFC
6/19/70	5m-07 sec	-	Acceptance at G.E.
6/19/70	5m-18 sec	-	Acceptance at G.E.
6/19/70	4m-54 sec	-	Acceptance at G.E.

*Phase shift capacitor removed.

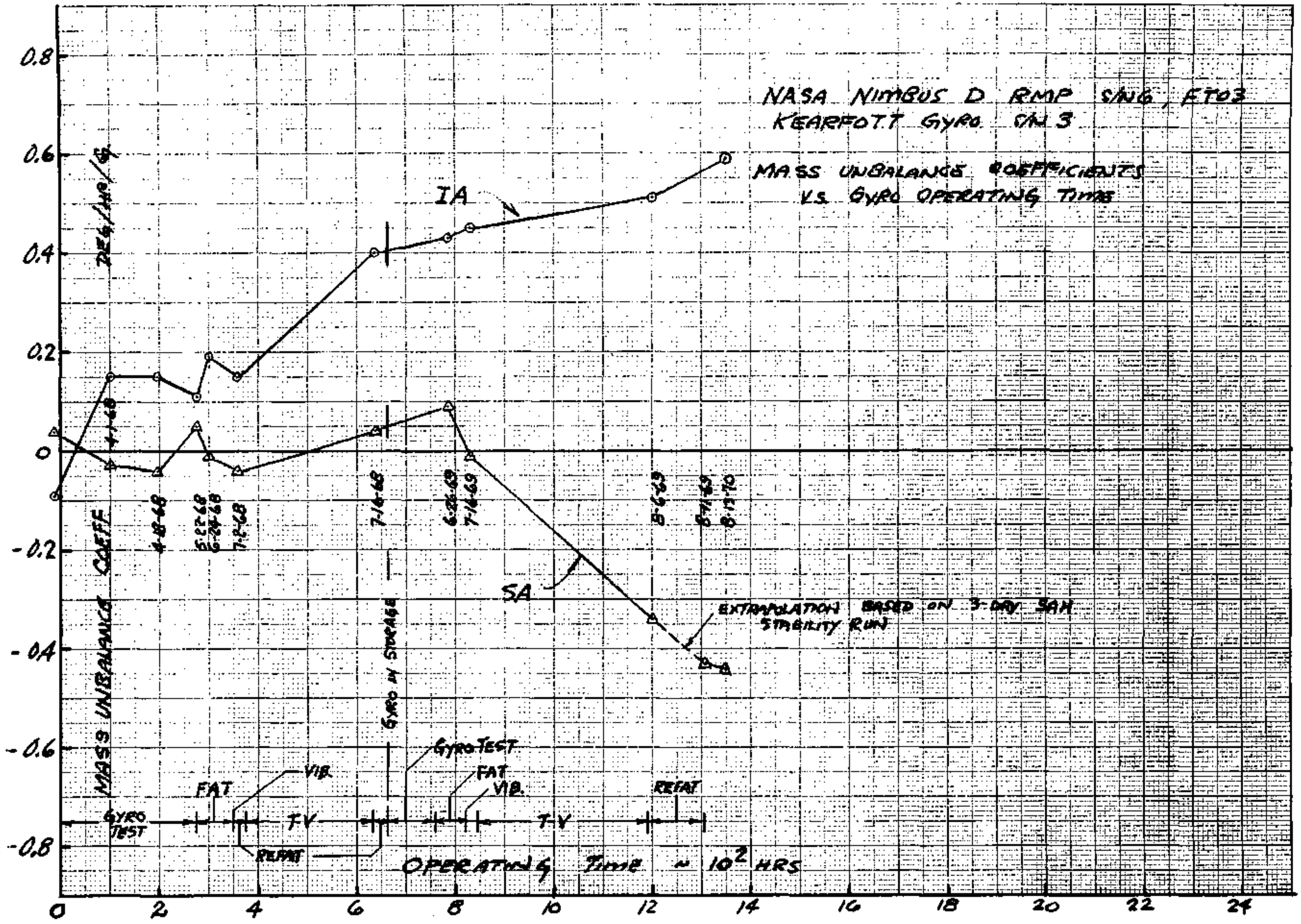

Figure 5. Mass Unbalance Coefficients vs Gyro Operating Time for Kearfott Gyro S/N 3

Table 14. Milestone Summary, RMP FT03

Milestone	Date
Gyro S/N 2 delivered to Sperry	12/28/67
Gyro S/N 2 completed gyro test	2/7/68
Gyro S/N 3 delivered to Sperry	2/14/68
Gyro S/N 3 completed gyro test	4/18/68
Pre-FAT of RMP S/N 6	4/22/68
Gyro S/N 2 installed	4/24/68
Complete FAT of RMP S/N 6	4/30/68
Vibration at GSFC	5/2/68
Complete thermal-vacuum test at Sperry	5/16/68
Acceptance test - gyro S/N 2 malfunction	5/21/68
Remove gyro S/N 2 from RMP S/N 6	5/22/68
Gyro S/N 3 installed in RMP S/N 6	6/21/68
Complete FAT of RMP S/N 6	6/27/68
Vibration at GSFC	7/1/68
Complete thermal-vacuum test at Sperry	7/14/68
Gyro S/N 3 removed for resoldering of connector	12/26/68
RMP S/N 6 disassembled and reassembled using the S/N 6A subassemblies	
Pre-FAT of RMP S/N 6	6/25/69
Gyro S/N 3 reinstalled in RMP S/N 6	6/26/69
Complete FAT of RMP S/N 6	7/1/69
Vibration at GSFC	7/15/69
Complete thermal-vacuum test at GSFC	8/5/69
Final acceptance test at GSFC	11/5/69
Special test at Sperry	11/7/69
Delivery to G. E.	4/6/70

- Vibration Test per T/Spec #4310-10680. Functional data after tests acceptable. See pages 22 and 23 in Log book. Vibration input curves retained at GSFC. Test date 1/23/69.

- Factory Acceptance Test per T/Spec #4310-10678C, paragraphs 7.7 7.13, 7.15, and 7.17. Testing began on 1/24/69. Noted out-of-tolerance reading on the -12 vdc RMP supply (page 25 of Log book). Analysis indicated broken wire in harness. Since the break did not affect RMP operation, testing was continued and was completed on 1/24/69. Performance data was acceptable, and indicated an absolute bias of 0.016°/hr. The broken lead was repaired on 1/27/69, as described in CNAP #80 contained in Appendix VII. See pages 24 through 28 in the Log book.

- Thermal-Vacuum Test per T/Spec #4310-10679A. Functional data after test acceptable. See pages 28 through 34 in Log book. Test period 1/28/69 to 2/6/69.

- Factory Acceptance Test per T/Spec #4310-10678C, paragraphs 7.7 through 7.13, 7.15, and 7.17. Performance data acceptable. Performance data indicated an absolute bias of 0.023°/hr which was a change of 0.039°/hr during the thermal-vacuum test sequence. See pages 35 through 39 in Log book. Test period 2/6/69 to 2/7/69.

Gyro S/N 4 performed well throughout the test phases at Sperry. The wheel rundown summary, presented in table 15 may have indicated a slight downward trend in the total times. This unit eventually experienced apparent wheel seizure while in orbit after nearly 10,000 hours of operation.

Table 16 lists significant milestones in the history of RMP FT04.

5.4 Integration of the Kearfott Ball Bearing Gyro

5.4.1 Background. In June 1966, during formulation of the FY'67 Nimbus program, a task was included to study the possibility of retrofitting the Kearfott Alpha 2 gyro into the RMP in order to provide a back-up to the SYG-4200 gyro program.

Preliminary studies were carried out at Sperry during the Fall of 1966, primarily in the area of the command logic to be employed with the Kearfott gyro. Proposed relay card schematics were generated.

On 30 January 1967, NASA informed Sperry that a tentative decision had been made to incorporate the Kearfott gyro into the Nimbus D RMP with the provision that the changes to the circuitry permit future interchangeability with the SYG-4200 gyro, when it was successfully qualified.

A trip was made to Kearfott on 6 February 1967 to establish a firm interface definition of the gyro type to be used.

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Table 15. Gyro Wheel Rundown Summary, Kearfott Gyro S/N 4

Date	Total	30-0 Hz	Test
2/8/68	-	53.0 sec	Kearfott
5/29/68	4m-50 sec	-	Gyro FAT
6/21/68	4m-10 sec	-	Gyro FAT
1/10/69	4m-12 sec	-	Gyro retest after new connector
1/18/69	4m-12 sec	50.5 sec	RMP FAT (FT04)
1/20/69	4m-01 sec	46 sec	RMP FAT (FT04)
1/21/69	4m-01 sec	45 sec	RMP FAT (FT04)
1/22/69	3m-54 sec	45 sec	RMP FAT (FT04)
1/22/69	4m-00 sec	50 sec	RMP FAT (FT04)
1/23/69	3m-57 sec	-	Vibration at GSFC
1/23/69	3m-58 sec	-	Vibration at GSFC
1/23/69	4m-00 sec	-	Vibration at GSFC
1/24/69	4m-06 sec	47 sec	Post vibration FAT
1/24/69	4m-01 sec	49 sec	Post vibration FAT
1/24/69	4m-05 sec	51 sec	Post vibration FAT
2/6/69	3m-52 sec	-	End of T-V
2/6/69	3m-51 sec	46 sec	Post T-V FAT
2/6/69	3m-57 sec	48 sec	Post T-V FAT
2/7/69	3m-54 sec	47 sec	Post T-V FAT
2/12/69	3m-35 sec	43 sec	Final acceptance test
2/12/69	3m-05 sec	41 sec	Final acceptance test

Table 17 summarizes the important interface characteristics of both the Sperry SYG-4200 gyro and the Kearfott C702564-015 gyro to be retrofitted. The problem areas indicated by asterisks (*), are individually discussed in following sections.

5.4.2 Spin Motor. The gyro spin motor excitation presented the area of greatest incompatibility with the existing electronics. The SYG-4200 gyro utilized a three-level, dual-frequency excitation scheme for starting and running, whereas the Kearfott gyro started and ran at a single voltage and frequency, greatly simplifying the turn-on procedure.

The design philosophy followed in incorporating the necessary change was to limit all modifications to the relay cards, adding wires as necessary to the harness. In this way, interchanging gyro types would involve changing relay cards only.

Table 16. Milestone Summary, RMP FT04

Milestone	Date
Gyro S/N 4 delivered to Sperry	2/14/68
Gyro S/N 4 completed gyro test	6/21/68
Thermal indicator on gyro S/N 4 inspected by Sperry, GSFC, and Kearfott personnel	8/7/68
Connector on gyro S/N 4 resoldered to pass X-ray inspection	12/ /68
Gyro S/N 4 completed retest	1/10/69
Pre-FAT of RMP S/N 7 completed	1/13/69
Gyro S/N 4 installed	1/15/69
Complete FAT of RMP S/N 4	1/22/69
Vibration test at GSFC	1/23/69
Complete thermal-vacuum test at GSFC	2/6/69
Complete acceptance test at Sperry	2/12/69
Delivery and acceptance test at G.E.	3/5/69

Table 17. Gyro Parameter Summary

		Sperry SYG-4200	Kearfott C-702564-015	
Spin Motor				
Excitation frequency (Hz) -	24,000 rpm	800	400	*
	12,000 rpm	400	N/A	
Starting power (Watts)		16	3.75 Max.	
Running power (Watts)	24,000 rpm	4.0	3.2 Max.	*
	12,000 rpm	1.8	N/A	
Excitation voltage (0-peak square wave)	Start	52	N/A	
	Run, 24,000 rpm	29	29	*
	Run, 12,000 rpm	14	N/A	
Angular momentum	24,000 rpm	136,000	227,000	
	12,000 rpm	68,000	N/A	
Phase shift capacitor (ufd)	800 Hz, Start	1.3	N/A	
	800 Hz, Run	0.8	N/A	
	400 Hz, Run	2.8	1.3	*

Table 17. Gyro Parameter Summary (Cont.)

	Sperry SYG-4200	Kearfott C-702564-015	
Signal Generator			
Excitation frequency (kHz)	5	5	
Excitation voltage	3.5	3.5	
Gradient (mv/mr)	40	2.4	*
Input impedance (ohms)	42 + j156	100 + j472	*
Output impedance (ohms)	1600 + j3100	58 + j45	
Torque Generator			
Scale factor (deg/hr/ma) – 240,00 rpm	75	134	
12,000 rpm	150	N/A	
Resistance (ohms)	10	45	
Temperature Control and Monitor			
Heater resistance (ohms) – control	35	31.4	
warm-up	N/A	132	
Control sensor resistance (ohms)	1440	780	*
Sensor gradient (ohms/°F)	3	1.5	
Operating temperature (°F)	160	165	
Monitor sensor resistance (ohms)	16K	780	*
Output Axis Characteristics			
Gyro gain (H/D)	8	12.4	
Time constant (millisecond)	13	6.4	
Angular freedom (degrees)	±0.8	±2.4 min	
Inertia (GM-CM^2)	107	117	
Physical Characteristics			
Diameter (inches)	2.25	2.01	
Length (inches)	3.86	3.17	
Weight (pounds)	1.75	0.85	

The power conditioning card, 4216-67677, as designed for the SYG-4200, processed the 400 Hz, 2-phase clock to produce either 800-Hz or 400-Hz drive to the inverter, depending on the presence, or absence of a ground on terminal 13 of the card. Grounding this input to produce the 800-Hz output also disabled the under-voltage cut-out circuit, to prevent loss of wheel excitation during launch.

Since there was no need for the under-voltage protection with the Kearfott ball-bearing gyro, and in fact it would have been undesirable, it was decided to permanently ground terminal 13 of the power conditioning card via the new relay card to be designed. To achieve a 400-Hz drive signal to the inverter, it was then necessary to disable one of the 400-Hz clock inputs. This was accomplished by grounding terminal 8 of the power conditioning card, again via the new design relay card. This required a new wire to be added to the harness (J9-8 to J6-21).

The inverter design for the SYG-4200 gyro included three phase-shift capacitors connected in various combinations via relay contacts for the three different gyro operating modes. The 0.82-ufd capacitor was permanently connected to the motor while either the 0.47 or 2.0-ufd capacitor was parallel with it by grounding through relay contacts. To achieve the single 1.3-ufd value recommended by Kearfott, the new relay card design simply connected the 0.47-ufd capacitor to ground (without a relay) and ignored the 2.0-ufd capacitor, producing a fixed value of 1.29 ufd.

In arriving at a command logic scheme to be incorporated in the new relay cards, discussions were held with Kearfott regarding gyro turn-on procedure. It was subsequently decided that the RMP ON command should energize the gyro feedback loop and heater but not the spin motor. A separate "Motor-on" command was provided with the stipulation that the gyro reach some elevated temperature before energizing the spin motor. Kearfott felt that this would optimize bearing life.

The existing 29-volt tap on the inverter transformer was satisfactory for normal operation of the Kearfott gyro, and the 24-volt tap was included in the command scheme as a power-saving option via the lower motor voltage command.

5.4.3 Signal Generator. The Kearfott gyro signal generator design was basically compatible with the excitation voltage and frequency provided by the RMP electronics. But its output gradient (sensitivity) was less than that in the SYG-4200 gyro by a factor of 16. This was partially compensated for by adding a step-up transformer to the secondary circuit of the generator on the gyro normalization assembly. The transformer selected was the high reliability equivalent of UTC's D0-T52 connected to provide a 2.83 voltage step-up ratio. The 8-to-1 impedance step-up, coupled with the inherently low secondary impedance of the Kearfott signal generator, resulted in an equivalent secondary impedance that was still acceptably low.

The overall gyro transfer function, including the transformer, was 84 mv/mr IA, compared to 320 mv/mr IA for the SYG-4200 gyro. The 4-to-1 reduction in loop gain was deemed acceptable.

The higher primary impedance of the Kearfott signal generator made it necessary to reduce the value of the primary tuning capacitor located on the normalization assembly from 0.22 ufd to 0.1 ufd. While this value did not provide exact tuning, it was the nearest available value, and resulted in very little loading of the 5-kHz source.

5.4.4 Temperature Control and Monitoring. The temperature control sensor resistor incorporated in the Kearfott gyro had a value of 780 ohms at gyro operating temperature. The heater controller cards were trimmed to control at a value of 1440 ohms corresponding to the sensor value in the SYG-4200 gyros. This discrepancy was overcome by including a 660.0 ± 0.5-ohm padder resistor network on the gyro normalization assembly connected in series with the sensor. The penalty was less tight temperature control of the gyro as a result of the lower sensor gradient, but this approach kept the heater controller cards interchangeable for either gyro.

The temperature monitor sensor on the Kearfott gyro was identical to the control sensor with a value of 780 ohms at operating temperature. On the other hand, the SYG-4200 gyro utilized an array of four thermistors with a combined resistance of 16K ohms at temperature which was used in a simple divider circuit to provide the gyro temperature telemetry channel.

A circuit design was developed using several transistors to make the Kearfott monitor compatible with the existing T/M card circuitry and T/M format, but it was subsequently discarded in favor of the simpler approach of adding a thermistor to the Kearfott gyro.

An over-temperature switch was not incorporated in the basic Alpha 2 gyro design, as had been done in the SYG-4200 gyro, to protect against heater controller malfunction. To remedy this, a thermal switch assembly was designed, which included the temperature monitor thermistor, to be cemented to the +0A end of each gyro.

5.4.5 Mechanical/Thermal Considerations. The physical size of the Kearfott gyro presented no basic problems, other than the location of the cable exit which had to be relocated to avoid mechanical interference. New mounting ring and clamp designs had to be generated.

With its higher operating motor power, the Kearfott gyro required a lower thermal impedance mount to avoid heater cut-off at high spacecraft ambient temperatures. This was accomplished by designing the ring and clamp to be fabricated from stainless steel. The SYG-4200 gyro had been sandwiched between a pair of micalex rings for thermal isolation.

No changes were made to the gyro mounting bracket, with its optical reference mirror and Lord vibration isolators.

5.4.6 Heater Controller Card. While not specifically related to the Kearfott gyro retrofit, a partial redesign of the heater controller card was undertaken at this time to eliminate a problem experienced on the Nimbus B program. The card, as designed for Nimbus B, employed a 10-kHz heater cycling frequency derived from the 5-kHz excitation. The method of obtaining the 10-kHz dither signal resulted in its containing a residual 5-kHz sub-harmonic, which, depending on duty-cycle (power level), coupled varying amounts of 5-kHz into both the gyro pickoff output and the temperature-controller input. The result was limit-cycle operation of the heater controller over several narrow ranges of heater power demand. When the limit cycle occurred, it created large disturbances in the rate loop output. Since the condition occurred mainly in the 0-10% and 90-100% regimes, it was seldom a problem in test, and since the RMP was to be operated "heater-off" in orbit, would be no problem in flight.

It was felt that to operate the Kearfott gyro "heater-on" in orbit would be unacceptable, thus the redesign. The solution was to cycle the heater at a frequency that was not harmonically related to 5-kHz, or any of its odd harmonics. A free-running, relaxation oscillator was incorporated to produce the desired sawtooth dither signal. A study was made to determine a safe frequency range, resulting in the selection of 8000 ± 200 Hz for the trim condition of the oscillator. Also included in the redesign was elimination of the temperature-set trim potentiometer in favor of selected fixed trim resistors.

5.4.7 Electrical Stress Analysis. An electrical stress analysis, done on the Nimbus B RMP by the Reliability Engineering Department, was updated for the Nimbus D program to include the revised heater controller card and new relay cards. A report was issued and is included in Appendix VIII.

5.5 BTE Accomplishments

5.5.1 Bench Test Equipment Milestones. One set of bench test equipment was required to be fabricated and delivered under this contract. The BTE consists of a test console, interconnecting cable, holding fixture, and a self-test plug. The BTE was originally designed and two sets fabricated under the earlier Nimbus B RMP program, NAS 5-9571. One set was delivered to the General Electric Co., Space and Missile Division, the second set remained at Sperry. The third set of BTE was delivered to the System Engineering Branch at NASA/GSFC, Greenbelt, Maryland on 16 June 1967 as part of the Nimbus D contract, NAS 5-10391. Thus, identical test support equipment existed at Sperry, G.E., and NASA/GSFC for FAT, qualification and acceptance testing of the Nimbus D RMP units. Development of the BTE provided consistency of testing at each location plus a great deal of flexibility for diagnostic or retest as required.

The design and fabrication of the BTE was straightforward and relatively problem-free. Emphasis was placed on low cost, and provision for multiple-function capability. Multiple functional capability is provided by utilization of additional equipment such as scopes, wave analyzer, recorders, precision dc voltmeters, etc. This multifunction mode had been predicted and was wired into the basic test console.

A complete description of the bench test equipment, Sperry Part No. 4310-90535, is contained in the Nimbus Rate Measuring Package Bench Test Equipment Instruction Manual, Sperry No. CA31-0011, dated November 1967. The BTE instruction manual includes design and performance, operating instructions, theory of operation, maintenance and servicing, and a set of BTE schematics plus a replaceable parts list. The design and performance capability of the BTE has been discussed in paragraph 3.3 of this document. The theory of operation is technically noteworthy and will be discussed in the following sub-section. Consistent with the goals of this final report, the remaining topics will not be repeated in this document. Copies of the referenced manual exist at NASA/GSFC, G.E., and Sperry.

5.5.2 BTE Theory of Operation

5.5.2.1 Introduction. The primary function of the BTE console is to simulate the Nimbus spacecraft interface to the degree necessary for safe and proper operation of the Rate Measuring Package. Specifically, the BTE provides power, clock, and command input voltages, and incorporates means for monitoring the various RMP output voltages. In addition, the BTE provides a variable test current input to the RMP to simulate vehicle body rates.

The electrical functions incorporated in the BTE console may be categorized as follows:

- Clock circuit
- Command circuit
- Power supplies
- Rate test circuit
- Output monitor circuits
- 60-Hz power distribution and grounding

Each of the functions is described in detail in the following paragraphs.

5.5.2.2 Clock Circuit. The function of the clock circuit is to generate three square-wave reference signals. One of the signals has a frequency of 5 kHz, and a no-load voltage swing of 0 to -5.4 volts. The other two signals have frequencies of 400 Hz, no load swings of 0 to -24 volts, and are phase-displaced by 90 degrees.

The basic frequency source is a 40-kHz, crystal controlled oscillator that plugs into octal receptacle J52. The square-wave output on pin 7 of J52 has a no-load amplitude of 8 volts peak-to-peak.

Parallel counter circuits on the clock counter circuits card (Part No. 4310-65272) produce two separate reference frequencies. Integrated J-K flip-flops, FF1 through FF5, and buffer B1 are connected as a 25-to-1 counter producing an output of 1600 Hz. This signal is coupled via half of gate G1 to flip-flops FF9 and FF10 which are interconnected so as to produce a two-phase, 400-Hz output, buffered by G2.

A second counter consisting of FF6, FF7, and FF8 divides the original frequency by a factor of 8 producing an output of 5 kHz which is buffered by the second half of G1.

The clock output card (Part No. 4310-65273) contains three output amplifiers for the three clock signals from the clock counter card. Q1 and Q2 amplify the 5-kHz signal; Q3 through Q7 amplify the phase A, 400-Hz signal; and identical amplifiers, Q8 through Q12, amplify the phase B, 400-Hz signal.

5.5.2.3 Command Circuit. The function of the command circuit is to generate a command pulse of specified duration and transmit it to the desired RMP command input terminals.

The command pulse is initiated by depressing the spring-loaded toggle switch, S3 (Part No. 4310-65318). This immediately applies bus voltage, through the normally closed contacts of relay K3, to the wiper of the COMMAND SELECTOR switch, S2, which connects it to the desired RMP input terminal. This action also applies bus voltage to the network, C3, R4, and R5, on the bias supply card (Part No. 4310-65319), causing the voltage on the coil of relay K3 to slowly increase. After approximately 70 milliseconds, the coil voltage will be sufficient to operate K3 terminating the command pulse. Note that the pulse duration is independent of how long the COMMAND PULSE switch, S3, is depressed, as long as it exceeds the 70-millisecond network time constant. When S3 is released, network capacitor C3 is rapidly discharged through resistor R3 on the bias supply card.

5.5.2.4 Power Supplies. The BTE provides three dc voltages to the RMP and, in addition, generates three others for the clock circuits.

The primary dc supply is a Kepco PRM 24-5 which is connected to terminals 1 and 2 at TB1. At the loads normally imposed by the RMP (0.2 to 1.0 amp), this supply generates 25.5 to 26.0 vdc. The supply is used primarily to provide inverter, heater, telemetry, and command pulse power to the RMP, but, in addition, provides excitation to the final stages of the 400-Hz clock output amplifiers.

The BTE also provides +10 vdc, and -10 vdc, low current supplies to the Nimbus D RMP for gyro bias trim. These two outputs are generated on the bias supply card by Zener diodes CR9 and CR10 in conjunction with the -25 vdc primary supply and +12 vdc supply.

Three internal dc supplies are required by the clock circuits. A +3 vdc supply comprised of filament transformer T3 and full-wave diode bridge CR8 through CR11, on the clock output card, provides excitation to the integrated circuit logic elements, and the first stages of the three clock output amplifiers.

A -6 vdc supply, used by the clock output amplifiers, is generated by Zener diode CR13 on the clock output card.

Finally, a +12.8 vdc supply, for the 40-kHz oscillator, is comprised of transformer T1 and rectifiers CR11 and CR12 on the bias supply card.

A turn-on interlock circuit, comprised of relays K1 and K2, controls the application of primary bus boltage to terminal J1-38 on the RMP to prevent an incorrect turn-on condition in the RMP. After turning on RMP INPUT switch, S5, an RMP OFF command, COMMAND SELECTOR, position 1, must be transmitted to energize the latch K1 which in turn connects bus voltage to the RMP. K2 is connected so that the above sequence in reverse will not energize K1. In addition, the coil of K1 is returned to ground via a jumper in the RMP, so that if the RMP is not connected, or the connection is interrupted, K1 becomes deenergized, and cannot be reenergized without performing the correct turn-on sequence.

Provisions are made for connection of an auxiliary dc supply to terminals TB1-5 and TB1-6 on the rear of the control panel chassis. The jumper strap from TB1-4 to TB1-5 must be removed when an auxiliary supply is used. Note that the auxiliary supply connects only to certain inputs of the RMP and does not excite any BTE internal functions.

5.5.2.5 Rate Test Circuit. The function of the rate test circuit is to inject a variable dc current into the RMP gyro rate loop to simulate various levels of vehicle body rate. The circuit consists of an isolated, Zener diode-regulated 5.1 vdc supply, and associated attenuator and switching circuitry.

The isolated dc supply is comprised of transformer T2 and a diode bridge, CR1 through CR4, on the bias supply card. The output is regulated by Zener diode CR5 and connected to attenuator resistors R14 through R24. The RATE TEST AMPLITUDE switch, S9 selects the eight attenuator outputs. Positions 2 through 5 provide fixed current levels of 10, 7.5, 5, and 2.5 milliamps. Positions 6 through 9 provide adjustable current levels with maximum ranges of 1 ma, 160, 16, and 1.6 microamps. Adjustment is provided by potentiometer R2.

Since the variable current source is isolated from ground, it can be connected to the RMP either as a positive or negative source. This is accomplished by RATE TEST MODE switch, S6.

An auxiliary test mode is provided by RATE LOOP MODE switch S7. In position 2, OPEN LOOP, it short-circuits the rate loop amplifier output in the RMP, permitting the gyro float to be torqued open loop by the rate test circuit.

5.5.2.6 Output Monitor Circuits

5.5.2.6.1 AC Monitor. The ac monitor circuit is comprised of the AC MONITOR switch, S11, and the ac meter, a Triolab Model 109-1 vacuum tube voltmeter. The monitor switch provides selection of nine ac functions; three are the clock amplifier outputs and the remainder are RMP test points. An OFF position permits the meter to be used independently via jacks J1 and J2 which are permanently connected to the meter inputs. Alternately, J1 and J2 permit an oscilloscope or auxiliary meter to simultaneously monitor whatever is being monitored by the ac meter.

5.5.2.6.2 DC Monitor. The dc monitor circuit is comprised of the DC MONITOR switch, S8, and the dc meter, a Triolab Model 310-2, solid-state voltmeter. The monitor switch provides selection of eleven dc functions; six are internal BTE outputs and the remainder are RMP test points. An OFF position permits the meter to be used independently via jacks J3 and J4 which are permanently connected to the meter inputs. Alternately, J1 and J2 permit an oscilloscope, recorder, or auxiliary meter to simultaneously monitor whatever is being monitored by the dc meter.

The CURRENT MONITOR switch, S12, permits position 1 on the DC MONITOR switch to monitor two functions, though not simultaneously. When the CURRENT MONITOR switch is OFF, position 1 on the DC MONITOR is the main bus voltage. When the CURRENT MONITOR switch is ON, position 1 becomes bus (RMP input) current as determined by the voltage drop across R3, R4, and R5. R3, R4, and R5 are composition resistors permitting turn-on current transient measurements to be made across jacks J9 and J10 to frequencies beyond 1 MHz.

5.5.2.6.3 Telemetry Monitor. The telemetry monitor circuit is comprised of the TELEMETRY MONITOR switch, S10, the TELEMETRY OUTPUT meter, M2, and the meter amplifier consisting of Q1 on the bias supply card and associated components. The monitor switch provides selection of each of the twelve RMP telemetry channels.

Meter amplifier Q1 is connected as an emitter-follower with the 100-microamp meter, M2, connected from the emitter to zero adjust potentiometer R8 through the scale factor resistors R6 and R7. Diodes CR6 and CR7 provide compensation against temperature variation in the Q1 base-emitter voltage drop. Base current for Q1 is supplied by the telemetry channel being monitored and is approximately 1.5 microamps when the output meter is indicating -1 vdc, decreasing linearly to -0.5 microamp when the meter is indicating -6 vdc. If the base is open circuited, for instance by disconnecting the RMP, the meter will indicate in excess of full-scale.

5.5.2.6.4 Turn-On Counter and Elapsed Time Meter. A TURN-ON COUNTER is provided to display accumulated RMP turn-on sequences. It is a 5-digit, electromechanical, impulse counter. A current pulse flows through the counter's solenoid coil each time the RMP is commanded ON because of the rapid charging of capacitors C6 and C7 on the bias supply card when the contacts on relay K4 close. The coil of relay K4 and the RMP ON lamp, L4, are energized from the RMP upon activation of relay K1 in the RMP. When the RMP is commanded OFF, deenergizing K4, capacitors C6 and C7 are quickly discharged through resistor R25.

A second set of contacts on relay K4 is connected to ELAPSED TIME meter M4. This meter simply displays accumulated RMP operating time.

5.5.2.6.5 Power Distribution and Grounding. The 3-wire, 60-Hz power input cable from a standard receptacle, connects to terminals 1, 2, and 3 of terminal strip, TB3. The 60-Hz input is applied in series to switches S14 and S1, and then 5-amp fuse F1, before distribution to the various loads. The 60 Hz POWER switch, S1, is on the front panel, while S14 is located on the rear of the chassis for security purposes. Excitation to the power strips within the rear area of the console is obtained from terminals TB3-4, -5, and -6.

All dc and RMP input circuitry is grounded to the console frame via a single conductor from TB2. The console is connected to house ground via TB3-3. A 1/4-inch diameter grounding stud is provided on the rear of the chassis for connecting to the test stand.

Appendix I

KEARFOTT ALPHA II GYRO, OUTLINE DRAWINGS
AND PURCHASE SPECIFICATION

APPLICATION		REVISIONS
NEXT ASSY	USED ON	FOR REVISION RECORD SEE LAST SHEET

1. GENERAL:

PARTS SUPPLIED SHALL COMPLY WITH ALL THE REQUIREMENTS SPECIFIED ON THIS DRAWING AND ANY VENDOR'S NUMBER SHOWN ON THE PURCHASE ORDER.

2. REQUIREMENTS:

2.1 GENERAL: THE GYROSCOPE SHALL CONFORM TO ALL THE REQUIREMENTS OF P1581854 AND THIS DRAWING. IN THE EVENT OF CONFLICT, THIS DRAWING SHALL GOVERN.

2.2 FINISH: BLACK OXIDE

2.2.1 FINISH TO HAVE MINIMUM EMISSIVITY OF 0.6 AT 135°F. EMISSIVITY VALUE IS ESTABLISHED BY DESIGN.

2.2.2 FINISH NOT REQUIRED ON MOUNTING FLANGE.

2.3 WIRING AND INSULATION: PER MIL-W-81044/12

2.4 SOLDERING: ALL SOLDER JOINTS EXTERNAL TO HERMETIC SEAL TO CONFORM TO NASA NHB 5300.4(3A).

2.5 CONNECTOR:

2.5.1 TYPE: CONTINENTAL CONN. CORP. MM 20-22 PGDSL

2.5.2 CONTACT FINISH: GOLD PLATED PER MIL-G-45204. PLATING TO CONSIST OF 100 MILLIONTHS HARD GOLD. TYPE II. CLASS 2, ON 50 MILLIONTHS ~~SOFT GOLD~~, COPPER (MIL-G-14550) ON BASE MATERIAL OF CONTACTS. NO INTERMEDIATE PLATING TO BE USED.

◇ SPERRY ITEM CODES SEE EB699384 (CODE IDENT 56232)

◇ SPERRY ITEM CODE						OPERATIONAL NOTE
B	C	D	E	F	H	SPECIFICATION CONTROL DRAWING
					82	

REV				F	C	C	–	F	E	F	F
SHEET	11	10	9	8	7	6	5	4	3	2	1

SHEET INDEX

SPERRY CLASS CODE 6615-110

SHEET 1 OF 3 MUST NOT BE SUPPLIED TO VENDORS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DEC ANGLES ±.010

CONTRACT NAS 5-9571

DRAWN BY D McGullam DATE 16 JUNE 67

CHECKED BY DATE 16 JUNE 67

APPROVED FOR SPERRY R. DATE 22 AUG 67

APPROVED FOR SPERRY DATE 16 JUNE 67

APPROVED FOR DATE

SPERRY CLASS X

FIRST USED ON

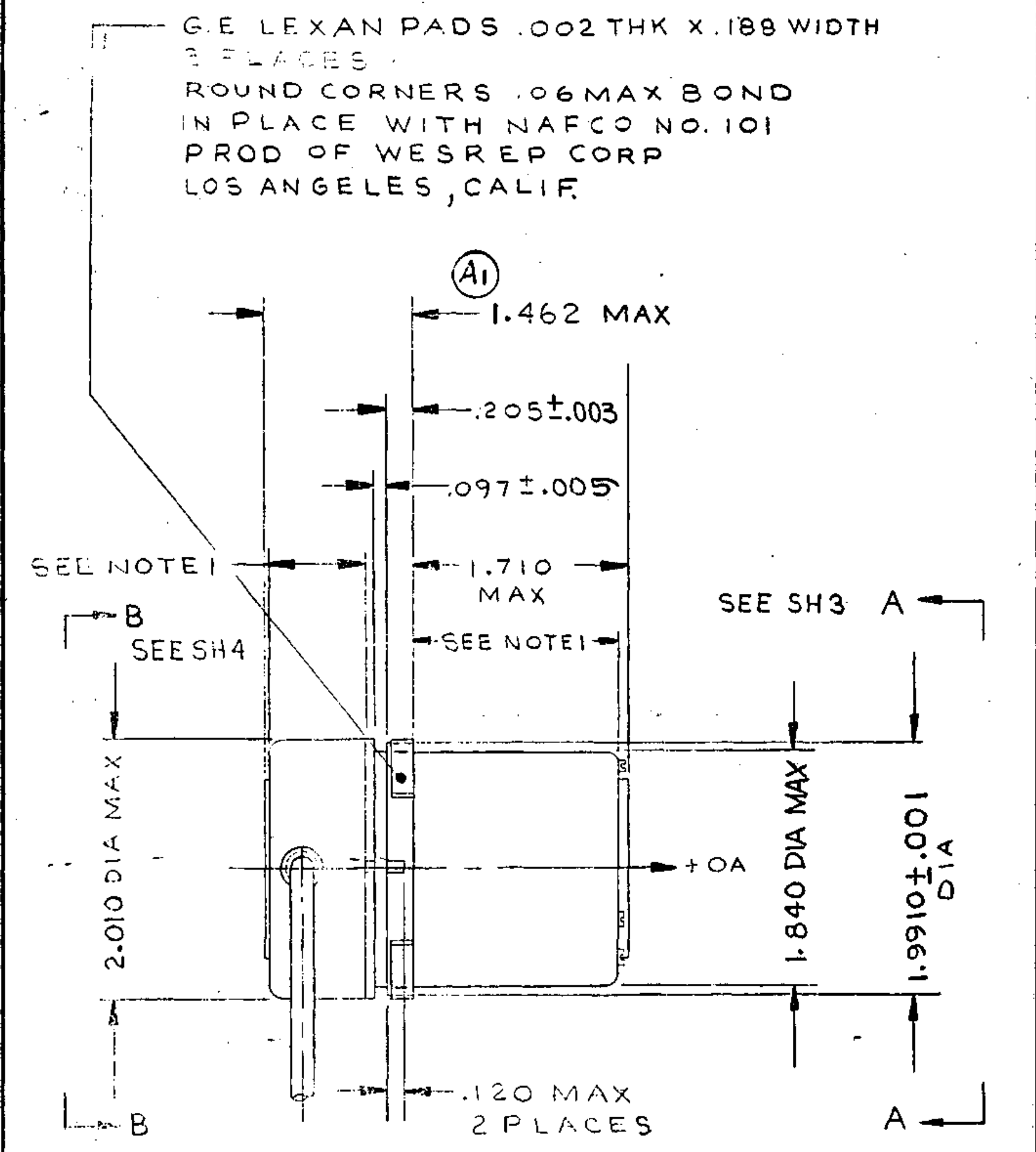
SPERRY GYROSCOPE COMPANY DIV OF SPERRY RAND CORP

TITLE GYRO, RATE INTEGRATING

CODE IDENT NO.	SIZE	DRAWING NO.	REV
56232	A	1200941	F
SCALE	UNIT WT	SHEET 1	OF 3

FORM No. 31 2155 K & E CO., N.Y.

1200941



SIZE	CODE IDENT NO.	DRAWING NO.	REV
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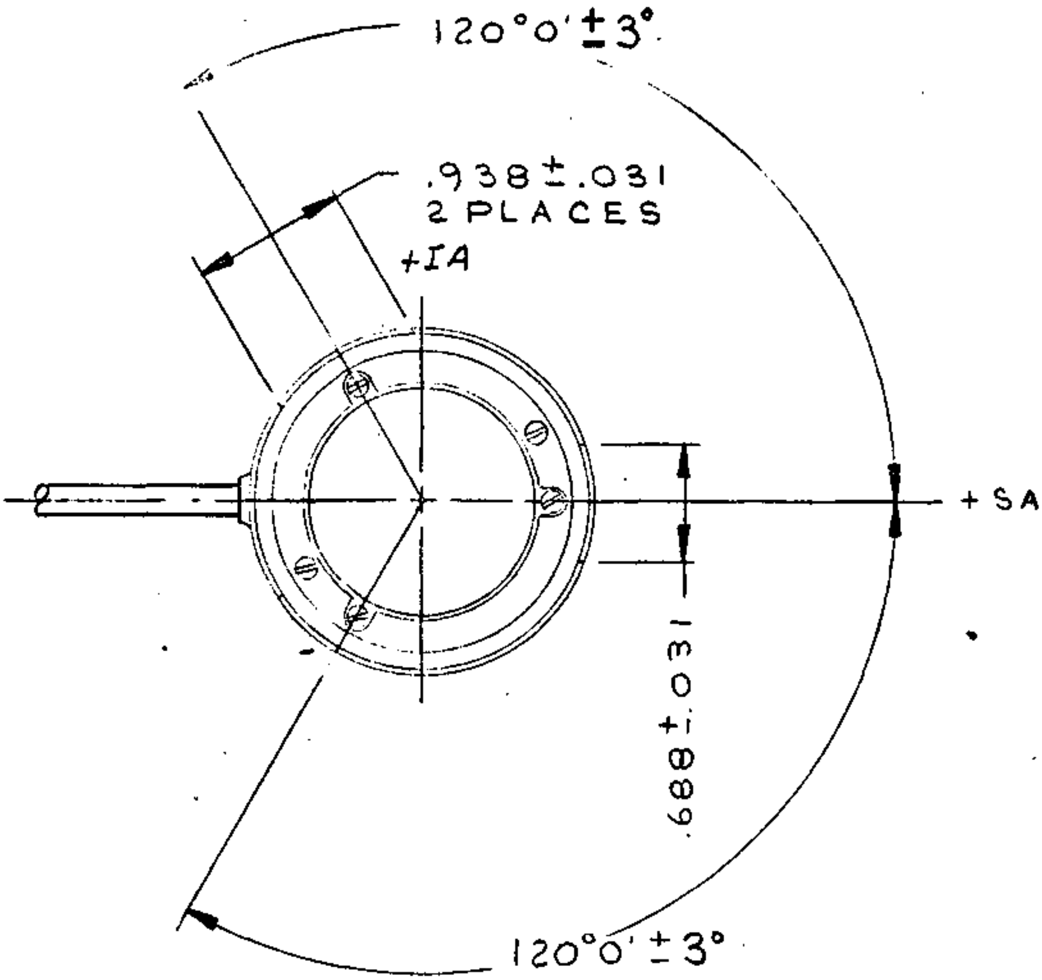
SCALE 1/1	UNIT WT	SHEET 2	

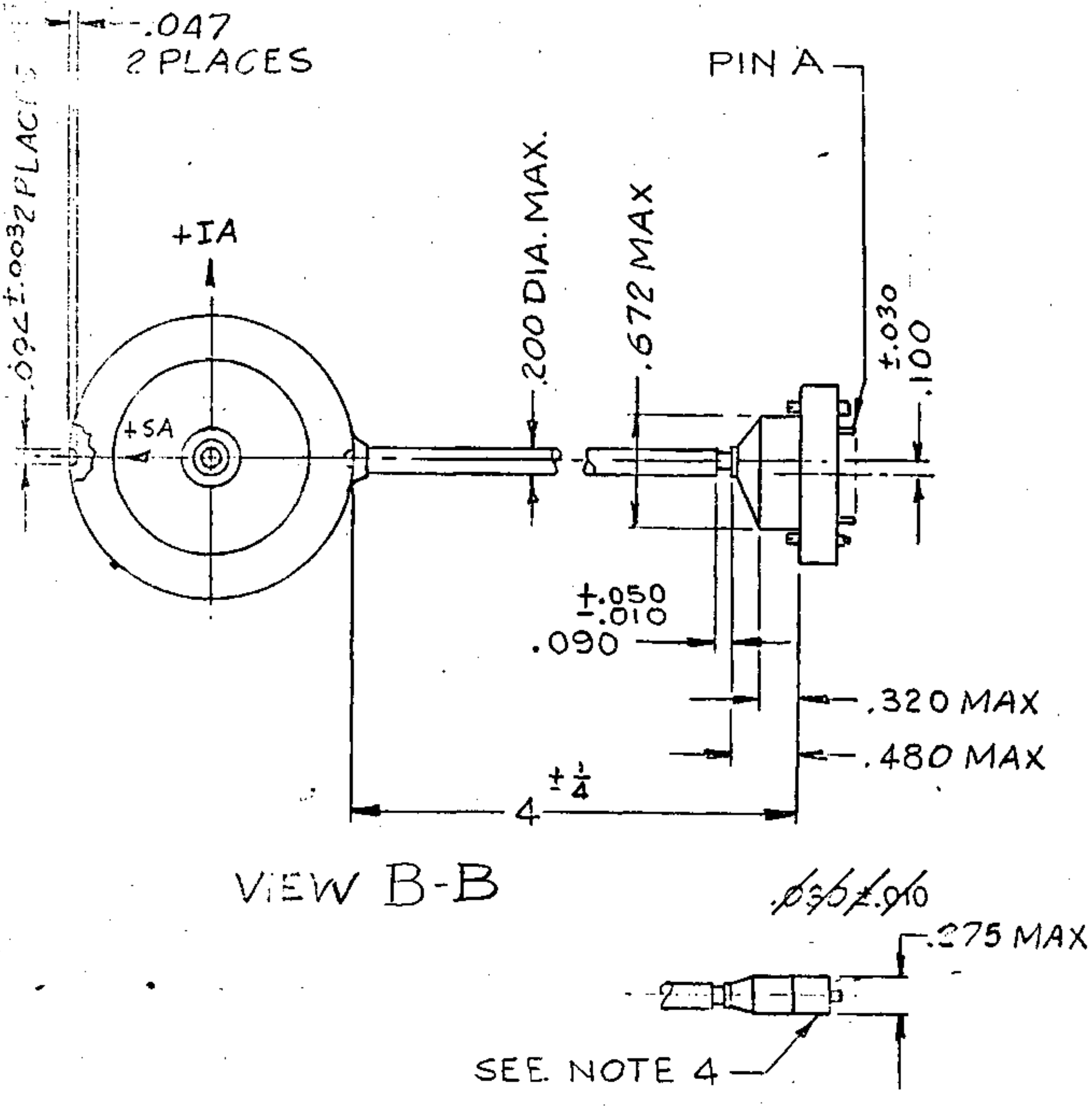


VIEW A-A

SIZE	CODE IDENT NO.	DRAWING NO.	REV
A	56232	1200941	E
SCALE 1/1	UNIT WT	SHEET	

SPERRY SPEC REFERENCED

FORM 65.5770 11 2155 K & E CO., NY



SIZE	CODE IDENT NO.	DRAWING NO.	REV
A	56232	1200941	F
SCALE	UNIT WT	SHEET 4	

SPERRY SPEC REFERENCED

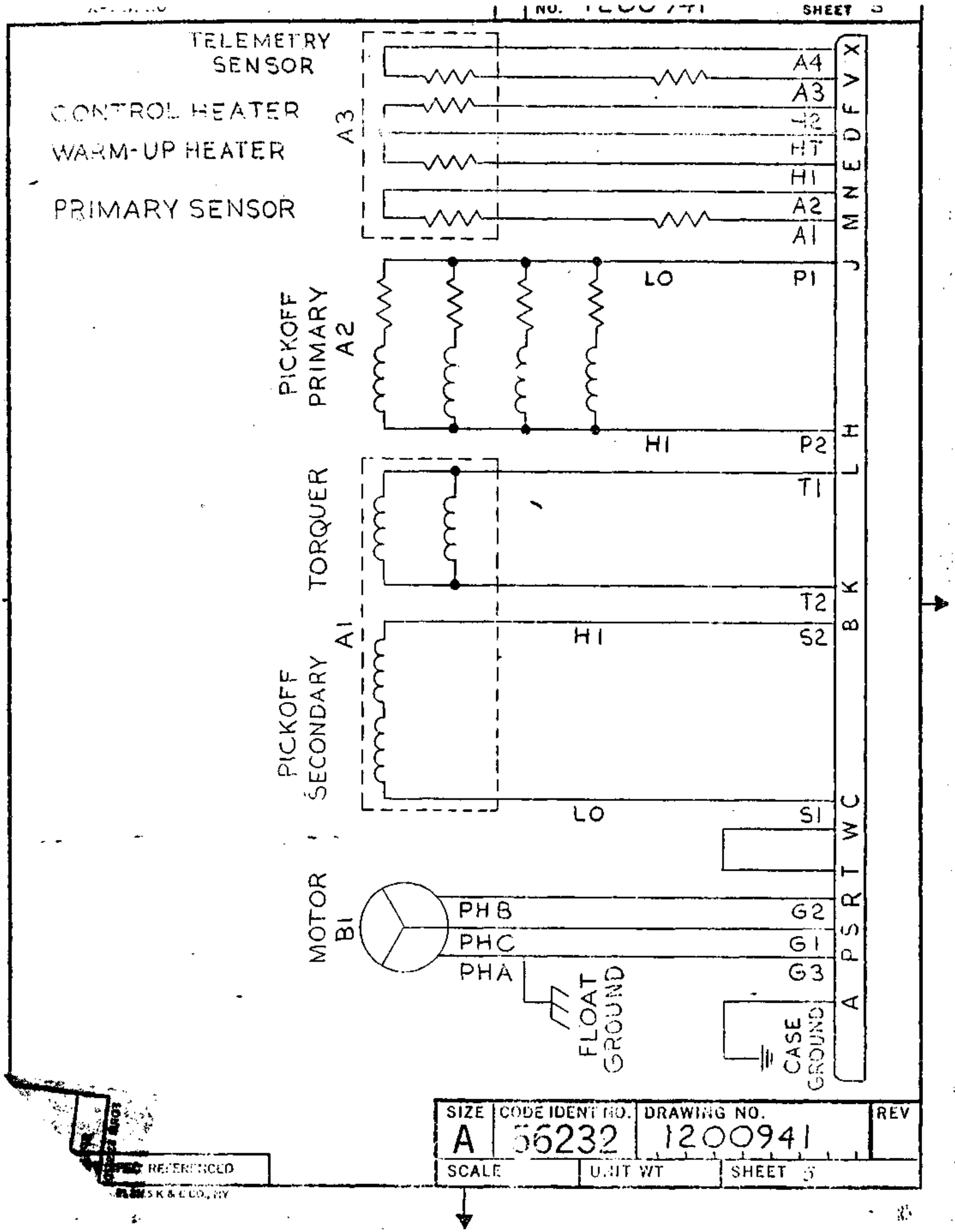
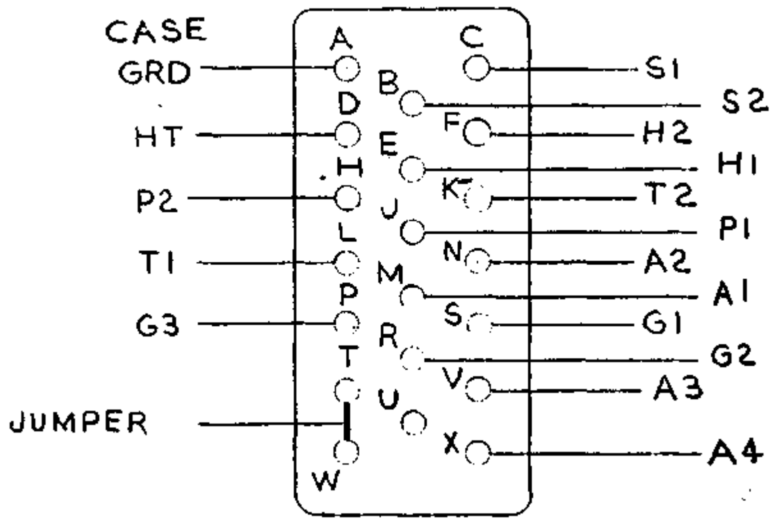

TELEMETRY SENSOR
CONTROL HEATER
WARM-UP HEATER
PRIMARY SENSOR
A3
A4
A3
HT
H1
A2
A1
X
V
F
D
E
N
M
J
LO
P1
PICKOFF PRIMARY A2
H
HI
P2
L
TORQUER
T1
K
T2
A1
B
HI
S2
PICKOFF SECONDARY
LO
S1
C
W
T
R
S
P
A
MOTOR B1
PH B
G2
PHC
G1
PHA
G3
FLOAT GROUND
CASE GROUND
SIZE
A
CODE IDENT NO.
56232
DRAWING NO.
1200941
REV
SCALE
UNIT WT
SHEET 5

TABLE I

TERMINATIONS	RESISTANCE AT ROOM TEMP.
P — P	94Ω± 15%
R — S	94Ω± 15%
P — S	94Ω± 15%
K — L	38Ω± 10%
H — J	15Ω± 10%
C — B	45Ω± 10%
M — N	630Ω± 15%
F — D	31.4Ω± 10%
E — D	132Ω± 10%
V — X	675Ω± 10%
T — W	1Ω MAX.
A — CASE	1Ω MAX.



CONNECTOR
WIRING

SIZE	CODE IDENT NO.	DRAWING NO.	REV
A	56232	1200941	C
SCALE	UNIT WT	SHEET	

SPERRY SPEC REFERENCED

3. SIGNIFICANT REQUIREMENTS:

CAUTION: THIS IS A PRECISION INSTRUMENT, HANDLE WITH EXTREME CARE.

3.1 MECHANICAL INSPECTION

3.1.1 INSPECT ALL MECHANICAL DIMENSIONS PER SHEET 2.

3.1.2 VERIFY CABLE LOCATION PER SHEET 3.

3.1.3 VERIFY CABLE LENGTH AND CONNECTOR ORIENTATION PER SHEET 4.

3.1.4 GYRO WEIGHT

3.1.5 RECORD ALL DATA

3.2 ELECTRICAL INSPECTION:

3.2.1 PERFORM CONTINUITY AND RESISTANCE MEASUREMENTS PER TABLE I ON SHEET 6.

3.2.2 PERFORM ELECTRICAL INSULATION RESISTANCE MEASUREMENT TO CASE GROUND USING 250 VDC MEGGER. USE 1 MEGOHM RESISTOR IN SERIES. INSULATION RESISTANCE SHALL NOT BE LESS THAN 100 MEGOHMS.

3.2.3 RECORD ALL DATA.

SOURCES OF SUPPLY (VENDOR PART NO. MUST BE LISTED ON P.O.)
(SPERRY TO SUPPLY P1581854 TO VENDOR)

SINGER-GENERAL PRECISION, INC (05088)
KEARFOTT DIVISION
LITTLE FALLS, NEW JERSEY, 07424

PART NUMBER: ~~C-70-2564-015~~ C702564-015-1

SPERRY SPEC REFERENCED

SIZE	CODE IDENT NO.	DRAWING NO.	REV
A	56232	1200941	C
SCALE	UNIT WT	SHEET 7	

DWG NO. 1200941 SHEET 8

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
F	SHEET 1: SHEET INDEX REVISED WAS: SHEET 1 OF 7 SHEET 2: AT TOP 1.462 MAX DIM WAS: 1.460 MAX. .205±.003 DIM WAS: .205$^{+.002}_{-.001}$. .097±.005 DIM. WAS: .097±.004. AT BOTTOM 2.010 DIA MAX DIM WAS: 1.999 DIA MAX. AND 1.840 DIA MAX DIM WAS: 1.830 DIA. SHEET 3: IN VIEW B-B BOTTOM .320 MAX DIM WAS: .280 MAX. SHEET 8: REDRAWN, REPLACES REVISION "E" WITH CHANGES. SHEET 4: DIM ".094±.003 2 PLACES" WAS: ".094±.001" 2 PLACES. AND DIM. ".320 MAX" WAS: ".280 MAX." C.O. 012557	15 JUNE 1971	TAW JAS

LT.

SPERRY SPEC REFERENCED	SIZE A	CODE IDENT NO. 56232	DRAWING NO. 1200941	REV F		
	SCALE	UNIT WT	SHEET 8			

FORM G32978-C No. 1 2155 K & E CO., N.Y. 59686

STAMP ORIGINAL OR OFFICE COPY

MARK & SERIALIZE AS PER SECURITY REQUIREMENTS

SPERRY

SPERRY GYROSCOPE COMPANY
DIVISION OF SPERRY RAND CORPORATION
GREAT NECK, N. Y.

217638

ENGINEERING SPECIFICATION 4216 DEPARTMENT

SIGNATURES

PREPARED BY	APPROVED BY	APPROVED BY	DATE RELEASED
E. Sommer 4/20/67	R. Domini 4/20/67		4/20/67

PURCHASE SPECIFICATION - RATE INTEGRATING GYROSCOPE

REVISION RECORD

SUB-LETTER	ITEM NO.	LOCATION	CHANGED FROM	DATE	APPROVALS
A	1	3.1.1.c	Add 1.3 uf ± 10%	6/20/67	6/20/67
	2	3.1.2 b	Add 400 ± .04 Hz		
	3	3.1.2 e	Change 83.5 + j 410 to 100 + j 472		
	4	3.1.2 f	Change 68.0 + j 410 to 58 + j 45		
	5	3.1.2 g	Change 4.1 ± to 6 ± 3		
	6	3.2.10	Change equivalent peak to zero to peak (two places)		
	7	3.2.11	Change ± .11 to ± 10		
	8	3.4.5	Add: Random drift is calculated with 1 minute smoothing of data.		
	9	3.4.6	Change .05 to 0.10		
	10	3.4.12.2	Change leads to lugs		
	11	3.5.2.12	Add Spectrum from 20 to 2000 Hz		
B	1	3.1.1.b	Add - at 400 ± 0.04 Hz	9/15/67	9/15/67
	2	3.1.1.c	Change ± 10% to ± 3%		
	3	3.1.1.e	Rewrite para.		
	4	3.2.1.3	Rewrite para.		
	5	3.4	Add - All tests shall be run in a mutually agreeable test fixture		
	6	3.4.12.2	Add - See drawing #1200941		
	7	3.4.12.3	Add - See drawing #1200941		
	8	3.5.2.1.1	Add - See Figure 2, 3 and 4		
	9	3.10	Add, or 1 yr. which ever occurs first		
	10	Pgs.16,17 & 18	Added figures 2, 3 and 4		
C	1	4.1	Completely revised	8/27/68	R.D.
D		2.1	Completely revise to Nimbus E & F requirements.	8/6/70	R.D.
		3.1.2.b	Eliminate phase lock requirement		
		3.1.6	Added paragraph		
		3.2.1	Was 29.4 mv		
		3.4.9	Revised fourth sentence starting "The		

PAGE ___ OF 19 PAGES

SUPPLEMENTS A B C D

R 1581350

SPECIFICATION NO.

LATEST REVISION

SUB-LETTER A B C D

ENGINEERING SPECIFICATION	SPERRY RAND SPERRY GYROSCOPE DIVISION GREAT NECK, N.Y. 11020		SECURITY NOTATION
OF SPECIFICATION	PRODUCT:	DEPT:	CONTRACT:

TITLE:
PURCHASE SPECIFICATION - RATE INTEGRATING GYROSCOPE

PREPARED BY	DATE	APPROVED BY	DATE	APPROVED BY	DATE	CUSTOMER APPD	DATE
E. Sommer		R. Domini					

REVISION RECORD

LTR	PAGE	LINE	DESCRIPTION	DATE	APPROVED
D			3.5.1.4 Was 100% 3.5.1.6 Added "max." 3.5.2.3 Spec was S-653-P14; eliminated "prototype levels" 3.5.3.2 Was 100% 3.6 Added words "Sperry drawing No." 4.2.1 New paragraph 4.2.2 Was 4.2.1	8/6/70	R.D. 8/6/70 T.J.W. 8/6/70

SHEET INDEX	REV																		
	SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

SECURITY NOTATION:	SPERRY ITEM CODES			CODE IDENT NO. 56232	SPEC NO. F1581654	REV D
		F	H	REVISION RECORD SHEET		
				SUPPLEMENTS		

page 1A

PURCHASE SPECIFICATION

RATE INTEGRATING GYROSCOPE

1. SCOPE:

1.1 General: This specification outlines the requirements for a Rate Integrating Gyroscope to be used in the NASA NIMBUS Rate Measuring Package. The Rate Measuring Package is manufactured by the Sperry Gyroscope Co., Great Neck, New York.

2. APPLICABLE DOCUMENTS:

2.1 The following documents of the exact issue shown, form a part of this specification:

<u>Specifications</u>

- NASA/GSFC Specification for Quality and Reliability Provisions for NIMBUS E & F Procurements S-450-P-10 dated 1 October, 1969.

<u>Drawings</u>

- Sperry drawing no. 1200941, Rev. C, Gyro, Rate Integrating

3. REQUIREMENTS

3.1 Components

3.1.1 Spin Motor: The spin motor shall be as follows:

a. Characteristics: Synchronous, hysteresis type

b. Excitation Voltage: 27.5 v (min) to 29.0 v (max.) rms, single phase square wave, with phase shifting capacitor, at 400 ± 0.04 Hz.

c. Starting power shall be 3.75 watts (max.); running power shall be 3.2 watts (max.) with a 1.3 uf ± 3% phase shifting capacitor.

d. Starting and running currents shall be less than .154 amperes and .134 amperes respectively.

e. Rundown time repeatability: The wheel rundown time, as measured by the elapsed time required for the back electromotive force (EMF) to change from 30 cps to zero (0) cps shall not be less than 25 seconds nor more than 100 seconds, nor shall it deviate by more than +150 percent, -50 per cent from the value recorded at gyroscope final test at KSD. The run down time during the specified life of the gyro shall be within 25 and 100 seconds. The wheel rundown time shall be determined at gyro operating temperature, after the spin motor has been running for a minimum period of 1 hour (hr.).

3.1.2 Signal Generator: The signal generator shall be as follows:

a. Type: Air core differential transformer

b. Excitation Voltage: 3.5 ± .07 volts rms on the primary winding at 5000 ± 0.5 cps single phase.

c. Sensitivity: 2.36 ± 0.24 millivolts rms per milliradian gimbal displacement with excitation at nominal.

d. Linearity: ± 1% of full scale reading for gimbal travel up to ± 2.4 degrees

e. Primary Impedance: 100 + j 472 ohms ± 10% at 5000 cps and 70 deg. F.

f. Secondary Impedance: 58.0 + j 45.0 ohms ± 10% at 5000 cps and 70 deg. F

g. Phase Angle: Secondary voltage to the primary voltage shall be 6° ± 3 degree lagging when operating into a 5000 ohm load (minimum) at 70°F gyro temperature.

h. Input Current: .010 amperes (max.)

3.1.3 Torque Generator : The torque generator shall be as follows:

a. Type: Permanent magnet D'Arsonval

b. Scale Factor: 134 ± 13 deg/hr/ma direct current (dc) at signal generator null

c. Linearity: ± 0.05 percent at gimbal null for rates from zero (0) to 100 deg/hr. This linearity error is the max. deviation from the best straight line.

d. Resistance: 38 ohms ± 10 percent at 70 deg F (Control field dc resistance)

e. Control Field Time Constant: 55 microseconds (μsec) ± 10 percent at 70 deg F

f. Maximum Current: 150 milliamperes applied to torquer generator secondary

3.1.4 Temperature Sensing

3.1.4.1 Temperature Sensing Element: Primary: The temperature sensing element shall be adjusted to have a dc resistance of 780 ohms at operating temperature.

3.1.4.2 Temperature Sensing Element: Telemetry: The telemetry temperature sensing element shall be adjusted to track the primary sensor within ± 2.0°F, for all environmental conditions excluding warm-up.

REV YM

3.1.5 Heater Windings

3.1.5.1 Control Heater: The control heater winding shall be as follows:

a. Resistance - dc: 31.4 ± 3.1 ohms at 70 deg. F

b. Power - max.: 30 w when excited with 28 v dc

3.1.5.2 Warmup Heater: The warmup heater winding shall be as follows:

a. Resistance - dc: 132 ± 13 ohms at 70 deg. F

b. Power - max.: 112 w when excited with 115 v, 60 cps single phase

3.1.6 Gyro Fluid: The fluid used in the gyro shall be free of any bubbles and shall not solidify at temperatures above $0^{\circ}F$.

Prior to filling the gyro, the gyro assembly within the fill fixture shall be flushed with filtered Freon to such a degree that the particle count on a 0.45 micron Millipore filter placed in the flushing fixture for 15 minutes reaches the proper level. This shall be performed with the gyro positioned bellows end up and bellows end down. The acceptable particle count level shall be:

a. No particles greater than .003".

b. No more than 2 particles between .002" and .003".

c. No more than 10 particles between .001" and .002".

d. No more than 20 particles below .001".

e. No more than a total of 32 particles, as a practical limit.

3.2 Design and Construction: The design and construction shall be in accordance with the applicable specifications and outline drawings.

3.2.1 Gyro Transfer Function: The gyro open loop transfer function shall be 29.3 mv rms ± 2% output per milliradian displacement about the input axis when the signal generator excitation and spin motor excitation are held at the nominal values specified and the gyro is at operating temperature.

3.2.2 Output Axis Freedom: The gimbal freedom about the output axis shall be mechanically limited to ± 2.4 deg (minimum) from the signal generator null position.

3.2.3 Characteristic Time: The characteristic time is determined by dividing the gimbal moment of inertia about the output axis by the damping coefficient. It shall be 6.4 milliseconds (ms) ± 24 percent at operating temperature.

3.2.4 Angular Momentum: The Gyroscope, Integrating, shall be designed to have a nominal angular momentum of 227,000 gram (GM) centimeter (CM) squared per second (GM CM^2/SEC) at synchronous speed of 24,000 revolutions per minute (rpm).

3.2.5 Output Axis Inertia: The gimbal output axis inertia shall be approximately 117 grams centimeter squared ($gm\text{-}cm^2$).

3.2.6 Open Loop Gain: The open loop gain shall be 12.4 ± 19 percent at operating temperature.

3.2.7 Operating Temperature: The gyroscope operating temperature shall be 165 ± 2 deg. F.

3.2.8 Signal Generator Null: With the gyro at operating temperature and standard excitation applied to the spin motor, signal generator primary, and operating heater, the null or signal secondary voltage shall not exceed 1.0 mv rms.

3.2.9 Warmup Time: The time required for the gyro to reach operating temperature from 70°F shall be 30 minutes (max.)

3.2.10 Rate Mode Signal Noise: The max. value of noise measured in the output signal of a gyro operated in a rate mode shall not exceed an zero to peak rate of 0.2 deg/hr when measured under the following conditions at time of initial shipment, and shall not exceed 0-PK0.25°/hr over the life of the instrument. The rate loop parameters are as follows:

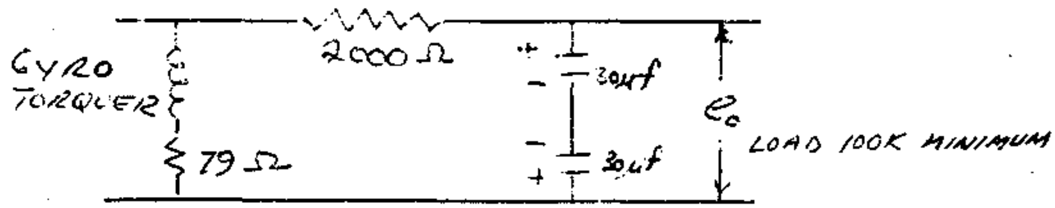
a. Amplifier Gyro Constant: closed loop velocity error coefficient, $K_v = 8.8 \pm 0.4\ sec^{-1}$

b. Loop Damping Constant: greater than critical

c. Loop Time Constant: 0.114 ± 0.011 sec

d. Frequency response of measuring equipment: DC to 60 Hz minimum

e. Output Filter: A filter with the configuration shown in Figure 1 shall be inserted between the gyro output signal and the instrumentation.



3.2.11 Temperature Sensor Gradient: The temperature gradient of the sensor shall be 1.57 ± 10% ohms per deg F over the range of 140 to 180 deg. F.

3.2.12 Input Axis Alignment: The gyro input axis shall be parallel to the plane defined by the gyro mounting flange surface within the following limits:

Nominal	Zero
Three sigma deviation	3.34 arc minutes
Worse case maximum	14.4 arc minutes

3.2.13 Interchangeability: Gyroscopes shall be interchangeable with respect to those parameters called out in the appropriate drawings and specifications.

3.3 Materials

3.3.1 Materials which are not covered by applicable specifications shall be of the best commercial quality, of the lightest practical weight and entirely suitable for the purpose. Nonflammable material shall be used to the greatest extent possible in the construction of the gyroscope.

3.3.2 Fungus Inert Materials: Materials which are not nutrients for fungus shall be used to the greatest extent practicable. Where materials that are nutrients for fungus must be used, such materials shall be treated with a fungicidal agent, or otherwise suitably protected.

3.3.3 Protective Treatment: When materials are used in the construction of the Gyroscope, Integrating, that are subject to deterioration when exposed to climatic and environmental conditions likely to occur during service usage, they shall be protected against such deterioration in such a manner that will in no way prevent compliance with the performance requirements of this specification. The use of any protective coating tha will crack, chip or scale with age or extremes of climatic or environmental conditions shall be avoided.

3.4 Performance

The following performance requirements are applicable under the environmental operating conditions listed under section 3.5.1 only. All tests shall be run in a mutually agreeable test fixture.

3.4.1 Acceleration Insensitive Drift Rate: The maximum value of acceleration insensitive drift rate with the gyro at null and with no external compensation shall be 2 deg/hr.

3.4.2 Acceleration Insensitive Drift Rate Shift:

3.4.2.1 The maximum change in acceleration insensitive drift rate, runup to runup with the gyro cooled to 70°F for 16 hours between operating periods shall be ± .5 deg/hr from the initial trimmed value for three consecutive runs.

3.4.2.2 The gyro ramp shall be less than 0.0015°/hr/hr during a 15 hour stability run, with output axis vertical. The 15 hour stability data shall be obtained during a stability test period of no greater than 30 hours.

3.4.3 Acceleration Sensitive Drift Rate (or Mass Unbalance Drift Rate) The maximum acceleration sensitive drift rate under any conditions of storage or operating environment shall be 1.0 deg/hr/g along the input axis (IA) and spin reference axis (SRA)

3.4.4 Acceleration Sensitive Drift Rate Shift (or Change in Mass Unbalance Drift Rate) The maximum change in acceleration sensitive drift rate shift runup to runup with the gyro cooled to 70 deg F for 16 hours between operating period shall be ± 0.5 deg/hr/g from the initial value for three runs.

3.4.5 Random Drift Rate The computed random drift (1 sigma value) for any operating position of the gyro for one-half hour shall not exceed 0.05 deg/hr. Random drift is calculated with 1 minute smoothing of data.

3.4.6 Anisoelastic Drift Rate The G^2 component of drift as computed from total drift rate data obtained with applied vibration over the frequency range of 30 to 1500 cps shall not exceed 0.02 deg/hr/g^2 peak; over the frequency range of 30 to 2000 cps shall not exceed 0.10 deg/hr/g^2 peak, except for isolated narrow frequency bands of less than 5 cycles.

3.4.7 Maximum Torquing Rate: The gyro shall be capable of a torquing rate equivalent to or exceeding an angular velocity about the input axis of 5.0 deg/sec.

3.4.8 Gyro Elastic Restraint (Off-Null): The nonacceleration sensitive drift resulting from the equivalent spring of the flex leads, signal generator and torquer generator shall not exceed 0.3 deg/hr per degree of gimbal displacement (output axis rotation) within the center 90 percent of the gimbal freedom range.

3.4.9 Gimbal Friction (Yozzle): Gimbal friction shall not exceed 1 deg/hr. The sum of all friction greater than 0.25 deg/hr shall not exceed 1.5 deg/hr. This parameter shall be checked from stop to stop with the spin motor off. The gimbal shall be driven from stop to stop at a rate of approximately 10 deg/hr. while recording the rebalance torque. This torque shall show no spikes or deviations greater than the aforementioned 1.0 deg/hr and the sum of all spikes and diviations greater than 0.25 deg/hr shall not exceed the aforementioned 1.5 deg/hr. This test shall be conducted from stop to stop four times in each of the following positions:

a. Positive OA up, positive IA north (horizontal)

b. Positive SRA up, positive IA north (horizontal)

c. Positive OA down, positive IA north (horizontal)

3.4.10 Vacuum Warmup: When the parallel combination of the control and warmup heater are excited with 24 w of dc power the sensor shall reach 160 deg F in 10.9 to 22.9 minutes. The signal generator secondary shall be at least 135 deg F when the sensor reaches 160 deg. F. The gyroscope shall be tested for this parameter while mounted in 13.5 ounce mounting fixture and maintaining a thermal resistance of 6 deg F per W between the instrument and a cold sink maintained at 75 deg F. This test shall be conducted under a pressure of not greater than 10^{-3} millimeters of mercury.

3.4.11 Tumble Trace Deviations: When tumbled about its output axis at rates of 300 deg/hr the torque to rebalance trace shall not deviate from its smooth curve by more than 0.5 deg/hr. The acceleration sensitive drift rates along either the IA or the SRA as calculated from the tumble test data shall not exceed 1.0 deg/hr per acceleration due to gravity. The acceleration insensitive drift as calculated from the tumble data shall not exceed 2.0 deg/hr.

3.4.12 Gyro Phasing

3.4.12.1 With the motor voltage phased as shown on Sperry drawing #1200941, the positive spin vector shall be as shown.

3.4.12.2 A positive rotation of the gyro case about the input axis should produce a signal generator voltage from pins C to B which lags the primary excitation voltage from pins J to H by 6±3 degrees. See drawing #1200941.

3.4.12.3 A positive rotation of the gyro case about the input axis should require current flow into torque generator pin K to hold the signal generator voltage at null. See drawing #1200941

3.5 Environments

3.5.1 Operating: The gyro shall perform as required herein when subjected to the following environments:

		Test	Space Orbit
3.5.1.1	Ambient Temperature (Sink)	70°F - 90°F	77 ± 4°F
3.5.1.2	Ambient Pressure	14.7 psia	10^{-5} MM Hg Abs
3.5.1.3	Gravity Forces	1 "G"	0 "G"'s
3.5.1.4	Relative Humidity	95% max.	-
3.5.1.5	Radiation	-	2×10^{7} rads
3.5.1.6	Magnetic Fields	1 Gauss max.	

3.5.2 Non-Operating Wheel On: The gyro shall perform in the environments specified in para. 3.5.1 above after being subjected to the following tests when mounted in the RMP.

3.5.2.1 Vibration:

3.5.2.1.1 Sinusoidal: ± 10 "g"s along the x, y and z axes (Figure 1A) respectively. Frequency range from 5 to 2000 cps at a one octave/minute sweep rate. Mounting bracket resonances up to 50 "g"s must be sustained for several seconds along each axis. See Figures 2, 3 and 4.

SPERRY GYROSCOPE COMPANY
DIVISION OF SPERRY RAND CORPORATION
GREAT NECK, N. Y.

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3.5.2.1.2 Random: 0.2 g^2/cps along the x, y and z axes respectively as measured at the mounting base of the RMP. Each axis shall be tested for a four (4) minute time period. Spectrum from 20-2000 Hz.

3.5.2.2 Acceleration: 30 "G"s shall be sustained along the thrust axis for a 5 minute time period. (See figure 1B)

3.5.2.3 Thermal Vacuum: The gyro shall be mounted in the RMP in the normal manner, and the system subjected to the thermal vacuum cycle (prototype levels) as shown in GSFC. spec S-320-NI-4.. The gyro shall be operated in the normal fashion during this test, and shall perform satisfactorily afterward per the requirements of this specification.

3.5.3 Non Operating Conditions: The gyroscope shall perform as specified herein after exposure to the following non-operating environments:

3.5.3.1 Storage Temperature: 0 to 180°F

3.5.3.2 Humidity - 0 to 95% (relative)

3.5.3.3 Vibration and Shock: The gyroscope shall not be damaged by vibration and shock encountered during normal and commercial transport and handling when packed for shipment in accordance with PK 1155*.

3.6 Dimensions and Mounting: The gyroscope outline dimensions, mounting details, and connector shall be as specified in Sperry drawing No. 1200941

3.7 Weight: The gyroscope shall have an approximate weight of 0.81 pound. Unit to unit variation shall not exceed 0.05 pound.

3.8 Workmanship: The gyroscope including all parts and accessories shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of soldering, wiring, impregnation of coils, marking of parts and assemblies, welding and brazing, painting, riveting, machine screw assemblies, and freedom from burrs and sharp edges.

3.9 Identification and Marking: The identification and marking of the gyroscope shall be in accordance with the requirements of MIL STD 130.

* Kearfott Spec.

3.10 Reliability and Life: The gyroscope shall have a mean time between failures (MTBF) design objective of 28,852 hours under laboratory conditions and a warranty service life of 5,000 hours or 1 year which ever occurs first.

4. QUALITY ASSURANCE PROVISIONS

4.1 Acceptance Tests: Acceptance tests in accordance with the following schedule shall be performed on all gyros furnished under the contract to assure conformance to the applicable specifications. The vendor acceptance tests shall verify conformance to the following paragraphs of this purchase specification.

Sperry Purchase Specification #P1581854 Paragraph	Title	Kearfott Accept. Test Procedure #C182564015 Paragraph
3.1.1.c	Motor Power	4.4.22
3.1.1.d	Motor Current	4.4.22
3.1.1.e	Motor Rundown Time	4.4.21
3.1.2.h	Sig. Gen. Input Current	4.4.8
3.1.3.b	Torque Gen. Scale Factor	4.4.14
	" " " "	4.4.18
	" " " "	4.4.20
3.2.1	Gyro Transfer Function	4.4.6
3.2.2	Output Axis Freedom	4.4.7
3.2.3	Characteristic Time	4.4.10
3.2.7	Operating Temperature	4.4.3
3.2.8	Sig. Gen. Null	4.4.9
3.2.10	Rate Mode Signal Noise*	4.4.24
3.4.1	Accel. Insen. Drift Rate	4.4.13
	" " " "	4.4.14
	" " " "	4.4.18
	" " " "	4.4.20
3.4.2.1	Accel. Insen. Drift Rate Shift	4.4.17
	" " "	4.4.19
	" " "	4.4.14
3.4.2.2	Ramp Drift Rate	4.4.16
3.4.3	Accel. Sen. Drift Rate	4.4.13
	" " " "	4.4.14
	" " " "	4.4.18
	" " " "	4.4.20

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Sperry Purchase Specification #P1581854 Paragraph	Title	Kearfott Accept. Test Procedure #C182564015 Paragraph
3.4.4	Acceleration Sensitive Drift Rate Shift	4.4.14
3.4.5	Random Drift Rate	4.4.15
3.4.7	Maximum Torquing Rate	4.4.23
3.4.8	Gyro Elastic Restraint	4.4.11
3.4.9	Gimbal Friction (Yozzle)	4.4.11
3.4.10	Vacuum Warmup	4.4.12
3.4.11	Tumble Trace Deviation	4.4.13
3.4.11	Tumble Trace Deviation	4.4.14
3.4.11	Tumble Trace Deviation	4.4.18
3.4.11	Tumble Trace Deviation	4.4.20
3.4.12.1	Motor Voltage Phasing	4.4.4
3.4.12.2	Signal Gen. Phasing	4.4.5
3.4.12.3	Torque Gen. Phasing	4.4.5

* Vendor data need not show rate loop parameters.

In addition, the vendor acceptance tests shall verify compliance with the mechanical and electrical requirements of paragraph 3, sheet 7 of Sperry Drawing Number 1200941.

4.2 Reports

4.2.1 Acceptance Test Data: One copy of the Acceptance Test Data Summary, Pages 1-6 and 18 of the Acceptance Test Log C182564015, Rev. A, shall accompany each unit delivered.

4.2.2 Failure Analysis: A failure analysis shall be conducted on all gyroscopes returned to Kearfott for repair under the provisions of the warrantee. The failure analysis shall consist of, but not be limited to the following items:

a. All performance failures shall be defined as:

1. Design failure
2. Nonconformance to design failure
3. Other (this category requires an explanation when used).

b. A detailed account of steps taken including the tests made to determine failure.

c) An explanation of the cause of the failure with sketches and/or photographs as necessary to depict or explain the failure.

d) An account of corrective action including a description of items repaired or replaced or of defective workmanship corrected.

e) A detailed description of action taken to prevent recurrence of the failure with specific effectivity.

f) Final test results on the item, if repairable, including detailed test data.

5. PREPARATION FOR DELIVERY

5.1 Packaging: Packing of the gyro shall conform to Kearfott instruction PK 1155. (Kearfott Spec.).

5.2 Marking: Intermediate and shipping containers shall be durably and legibly marked in accordance with Spec. MIL STD 129. A warning label shall be attached to the shipping container stating that the container shall not be subjected to temperatures below 32 deg. F.

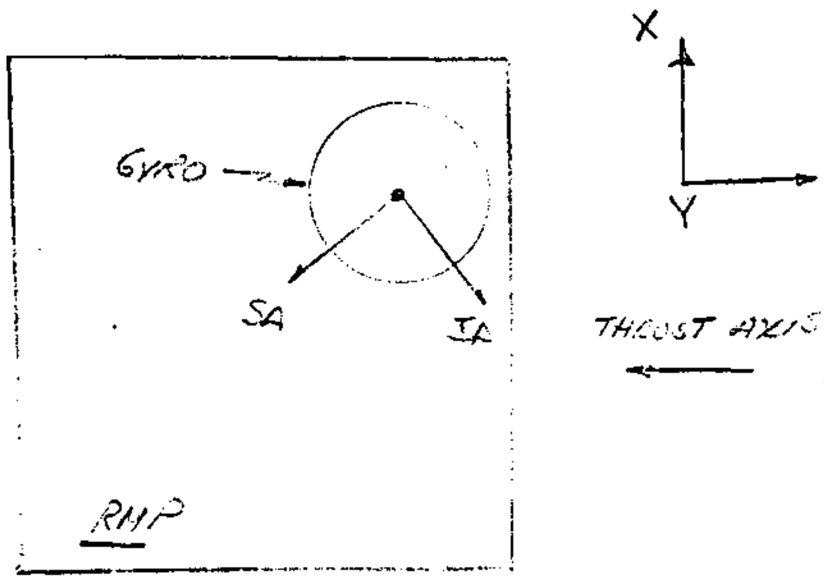
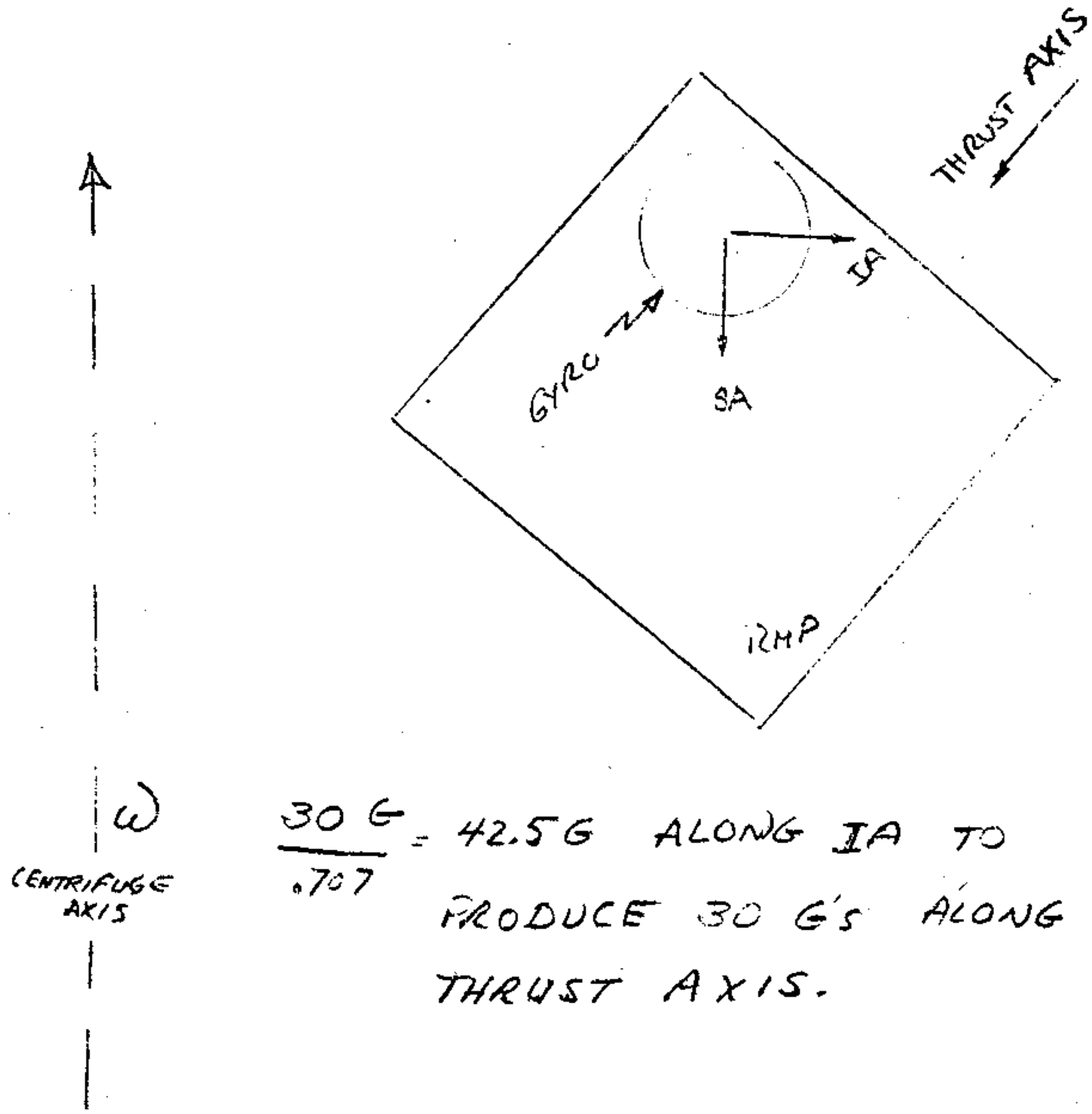


FIG 1 A

GYRO ORIENTATION IN RMP

DURING VIBRATION TESTS.



$\frac{30\,G}{.707}$ = 42.5 G ALONG IA TO PRODUCE 30 G's ALONG THRUST AXIS.

FIG 13

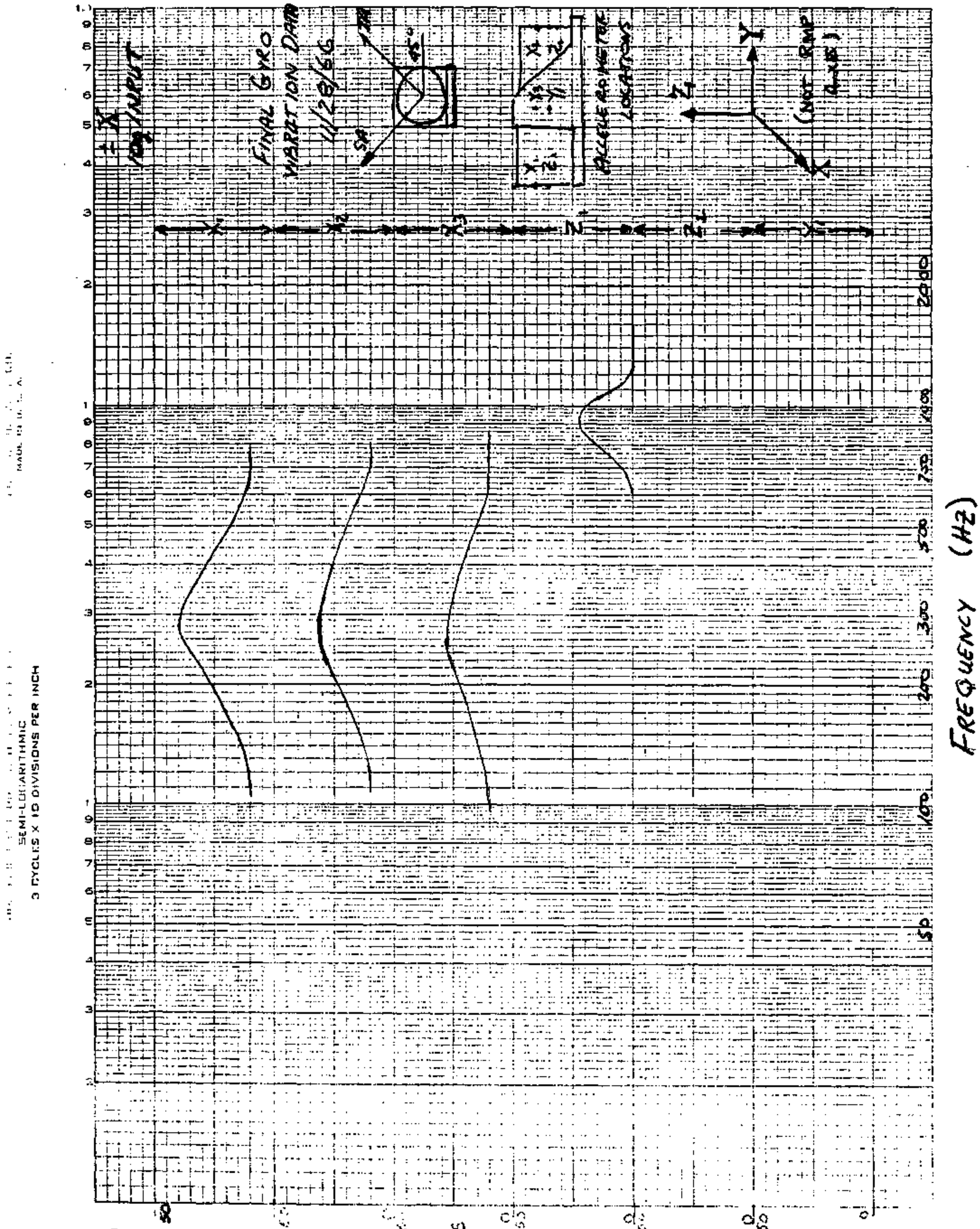


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FIGURE 2

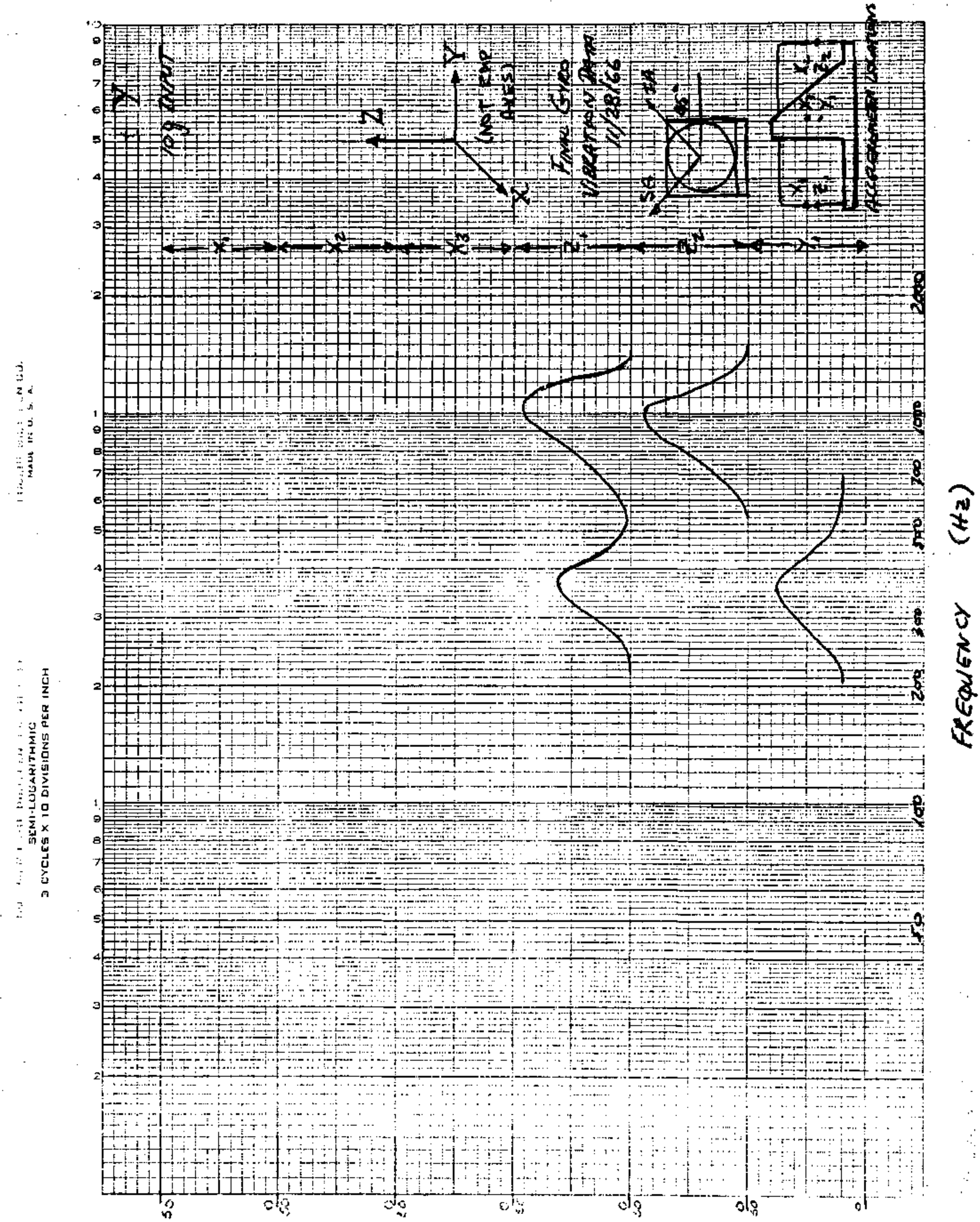

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FIGURE 3

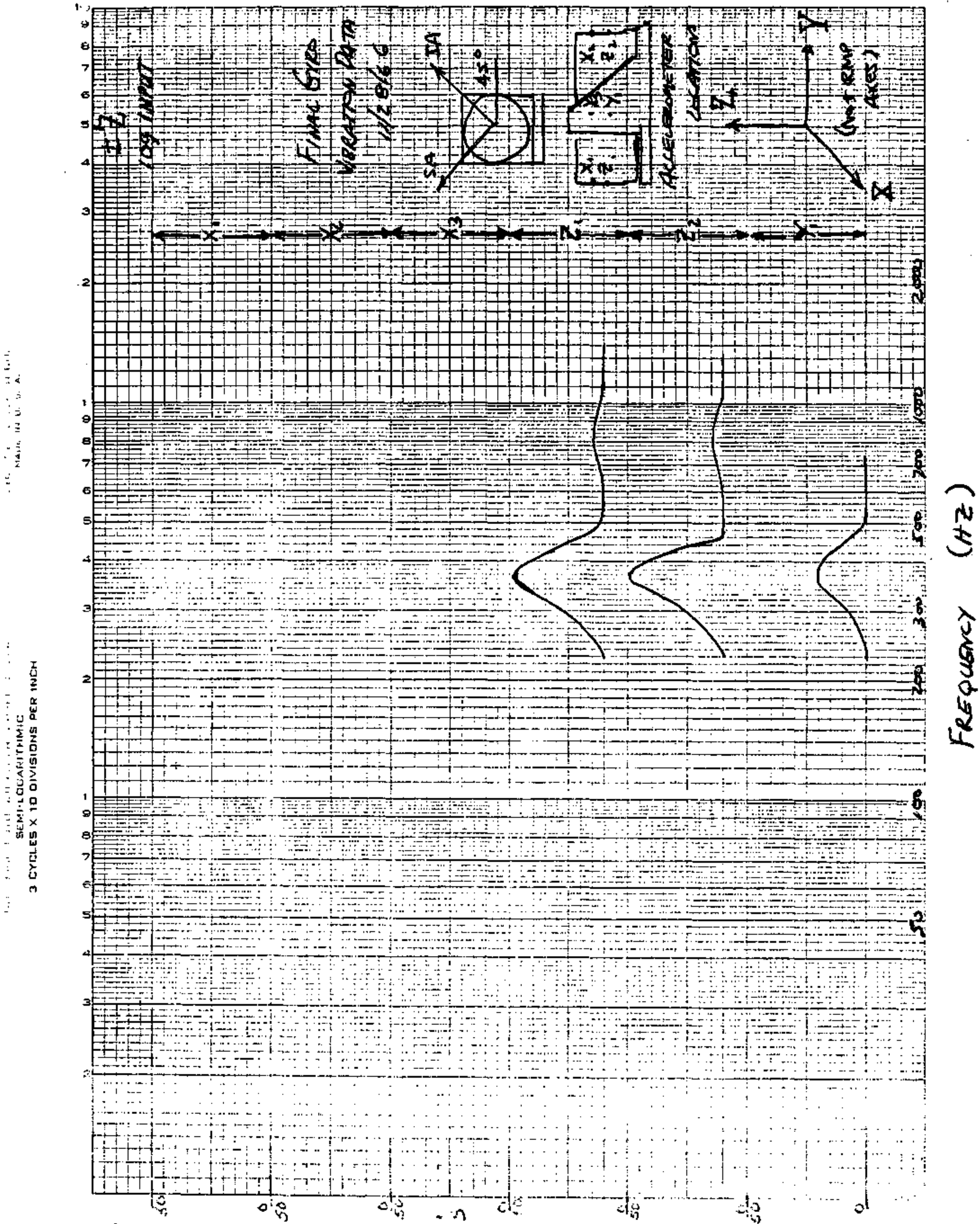

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FIGURE 4

Appendix II

PART SCREENING TEST PROGRAM FOR NIMBUS D RATE MEASURING PACKAGE

SUMMARY REPORT -

PARTS SCREENING TEST PROGRAM

FOR

NIMBUS "D" RATE MEASURING PACKAGE

P/N 4310-90641

CONTRACT NO. NAS 5-10391

Prepared for

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland

Prepared by

Reliability Engineering, Dept. 8220

SPERRY GYROSCOPE DIVISION
Sperry Rand Corporation
Great Neck, New York

Report No. SS-8220-6610 January 1968

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1. Introduction

This report summarizes the results of the parts screening test program conducted in fulfilment of the requirements of paragraph 4.8, GFSC specification S-450-P-1A for the NIMBUS "D" Rate Measuring Package program, Contract No. NAS5-10391.

2. Scope

The screening tests/tasks to which the applicable parts were subjected are indicated in Table 1. These tests/tasks were performed in accordance with the applicable Sperry Test Specifications: (T-4310-xxxxx) indicated in Table 1. These Sperry test specifications conform to the requirements of the applicable GFSC specifications referenced in Table 1. Approximately two (2) systems worth of applicable parts were subjected to screening in accordance with Table 1. The specific quantities of each part subjected to the screening tests are listed in Table 3.

3. Summary of Results

(1) Table 2 indicates those parts which failed to successfully complete the screening tests. All other parts tested successfully completed the screening process. Table 2 also provides an indication as to the distribution of the critical areas of failure.

(2) The greatest loss of components occurred during the Visual and Mechanical examination (76% of all rejections). The next most important cause for rejection; that described in the Internal Inspection requirements of the GSFC specification for High Usage Electronic Parts accounted for 14% of all rejections.

Within each of the above screening tests, several defect categories emerge as prime causes for rejection, e.g. cracked glass seals, these are indicated in Table 2. The remaining 10 rejected parts were randomly distributed amongst their associated screening tests as shown in Table 2.

TABLE 1
NIMBUS "D" RMP
PART SCREENING PROGRAM - TESTS/TASKS

Component	Sperry Test Spec. (Screening) T-4310-X	Markings	Visual Mech. Dim.	Bake	Inter-nal Insp.	Seal (Leak Test)	Bake Temp. Cycle	Temp. Cycl.	Funct. Test	Pulse Test	Vibra-tion	High Temp. Rev. Bias	Temp. Cycl.	Burn-in	Final Test
Capacitor, Fixed, Paper Dielectric, D.C. (Hermetically sealed in metallic case)	-10663	X	X			X		X	X					X	X
Resistor, Fixed Film (High Stab. type)	-10664A	X	X						X				X	X	X
Relay, Electromagnetic	-10665A	X	X			X			X		X			X	X
Filter, Radio Interference Reduction	-10666	X	X			X		X	X				X	X	X
Silicon Diode Semicond.	-10667	X	X		X	X			X					X	X
Zener Diode Semicond.	-10668	X	X		X	X			X					X	X
Transistor, Silicon NPN JAN2N1724	-10668	X	X		X	X			X	X				X	X
Transistor, Silicon NPN (all other P/N's	-10669	X	X		X	X			X					X	X
Transistor, Silicon PNP	-10670	X	X		X	X			X			X		X	X
Transisotr, Sil. Unijunc.	-10671	X	X		X	X			X					X	X
Microckt., I.C. Ampl.	-10672	X	X			X	X		X					X	X
Capacitor, Fixed, Ceramic Dielectric	-10673	X	X			X		X	X					X	X
Resistor, Var., Non-wirewound (Lead Screw actuated)	-10675	X	X	X					X				X	X	X

GSFC References:
GSFC Specification for Screening of Semiconductors, GSFC S-450-P-3
GSFC Specification for Screening High Usage Electronic Parts, GSFC S-450-P-4 (Capacitors, Resistors, Relays, Filters)
GSFC Specification: Workmanship, Marking, Traceability..., GSFC-323-P-2

TABLE 2
DISTRIBUTION OF REJECTS

Test/Task	Qty. Rejected	Defect	Device	Qty. Rejected	MIL Designation (No. of Rejects)
Visual and Mechanical Examination	43	Cracked glass seal	CR	14	1N691 (11) 1N645 (3)
			Q	29	2N930 (13) 2N1724 (13) 2N2907 (3)
	17	Void in glass seal of header	CR	15	1N645 (5) 1N970B (5) 1N971B (2) 1N645 (3)
			Q	1	2N1724 (1)
			Filter	1	GF 4000-1(1)
	11	Poor tinning	CR	5	1N691
			Q	6	2N930
Internal Inspection	5	Void between die and terminal post	CR	5	1N645
	4	Contact spring off longitudinal axis	CR	4	1N645
	2	Insufficient spring contact	CR	2	1N645
	2	Improper alignment of die	CR	2	1N970B
Leak Test	1		Q	1	2N1724
Functional Test	2	DWV	Relay	1	FIH-122
		T. Spec 4310-10672 Cond. 3.6.2.4	I.C.	1	1602497-1
High Temp. Rev Bias	2	Low BV_{CBO}, High Iceo	Q	2	2N2907
Final Test	5	High I_{EBO}	Q	2	2N1724
		High I_{CFS}	Q	2	2N930
		High $V_{CE\ sat}$	Q	1	2N2905

TABLE 3

SCREENING TASKS/TESTS
(Figure denotes number of parts surviving a given test)

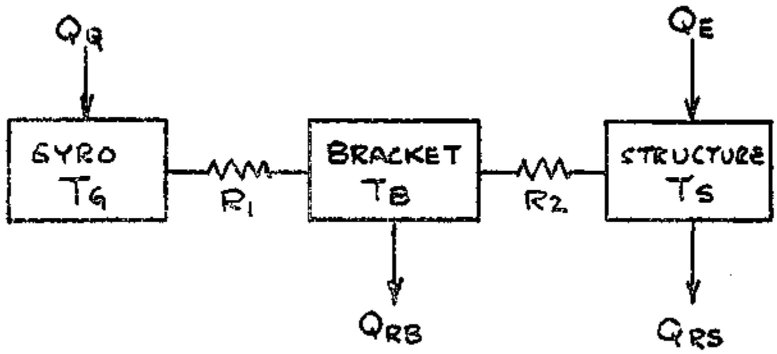
Component-MIL Designation	Test Qty	Markings	Visual Mech Dim.	Internal Insp.	Bake	Seal (leak)	Temp Cycl.	High Temp Bake Temp Cycl	Funct Test	Vibration	Pulse Test	Temp Cycl.	High Temp Rev. Bias	Burn In	Final Funct Test	Data Pkg.
Capacitor-MILC-25 CP09	23	23	23	-	-	23	23	-	23	—	-	-	-	23	22 (1)	22
Capacitor-MILC-11015 CK05	11	11	11	-	-	11	11	-	11	—	-	-	-	11	11	11
Relay FIM-12V. Potter Brumfield	20	20	20	-	-	20	-	-	19	19	-	-	-	19	19	19
Relay FCH-24V. " "	4	4	4	-	-	4	-	-	4	4	-	-	-	4	4	4
Relay FCH-12V " "	8	8	8	-	-	8	-	-	7	7	-	-	-	7	7	7
Resistor MILR-10509 RN60C	15	15	15	-	-	-	-	-	15	-	-	15	-	15	15	15
Resistor MILR-22684 RL07	6	6	6	-	-	-	-	-	6	-	-	6	-	6	6	6
Resistor MILR-10509 RN55	256	256	256	-	-	-	-	-	256	-	-	256	-	256	256	256
Variable Resistor MILR-22097 RJ12	10	10	10	-	10	-	-	-	10	-	-	10	-	10	10	10
SIL Unijunction Transistor JAN2N491	12	12	12	12	-	12	-	-	12	-	-	-	-	12	12	12
SIL Transistor NPN JAN2N910	97	97	97	97	-	97	-	-	97	-	-	-	-	97	97	97
SIL Transistor NPN JAN2N930	49	49	30	30	-	30	-	-	30	-	-	-	-	30	28	28
SIL Transistor NPN JAN2N1724	36	36	22	22	-	21	-	-	21	-	21	-	-	21	19	19
SIL Transistor NPN 3N74	14	14	14	14	-	14	-	-	13 (1)	-	-	-	-	13	13	13
SIL Transistor PNP JAN2N2907	28	28	25	25	-	25	-	-	25	-	-	-	23	23	22	22
SIL Zener Diode JAN1N967B	7	7	2	2	-	2	-	-	2	-	-	-	-	2	2	2
SIL Zener Diode JAN1N970B	15	15	10	8	-	8	-	-	8	-	-	-	-	8	8	8
SIL Zener Diode JAN1N971B	5	55	3	3	-	3	-	-	3	-	-	-	-	3	3	3
SIL Diode JAN1N645	200	200	194	182	-	182	-	-	179 (2)	-	-	-	-	179	179	179
SIL Diode JANUS1N691	78	78	62	39	-	39	-	-	39	-	-	-	-	39	39	39
DC Amplifier Microcircuit Sperry P/N 1602497-1	7	7	7	-	-	7	-	7	6	-	-	-	-	6	6	6
Filter Genistron GF 4000-I	6	6	5	-	-	5	5	-	5	-	-	5	-	5	5	5

(1) One lost in transport
(2) Two lost in transport

Appendix III

THERMAL ANALYSIS FOR NIMBUS D RATE MEASURING PACKAGE

THERMAL ANALYSIS - NIMBUS D RMP IN THERMAL-VACUUM CHAMBER WITH CRYOGENIC WALLS



The above diagram represents the presumed thermal model of the NIMBUS D RMP in a thermal-vacuum chamber using cryogenic walls for temperature control of the unit.

The various parameters are defined as follows:

T_G	Gyro temperature
T_B	Gyro bracket temperature
T_S	RMP structure temperature
R_1	Thermal resistance - gyro to bracket
R_2	Thermal resistance - bracket to structure
Q_G	Power input to gyro - motor + heater
Q_E	Power input to structure - electronics
Q_{RB}	Power radiated from bracket
Q_{RS}	Power radiated from structure

Equating the power input to power output of each element:

$$Q_G = \frac{T_G - T_B}{R_1} \tag{1}$$

$$Q_G = \frac{T_B - T_S}{R_2} + Q_{RB} \tag{2}$$

$$\frac{T_B - T_S}{R_2} + Q_E = Q_{RS} \tag{3}$$

Equating (1) and (2), eliminating Q_G results in:

$$T_B\left(1 + \frac{R_2}{R_1}\right) + R_2 Q_{RB} = \frac{R_2}{R_1} T_G + T_S \tag{4}$$

Rewriting (3) produces the following equation:

$$T_B - R_2 Q_{RS} = T_S - R_2 Q_E \qquad (5)$$

The equation for power radiated from a body to a completely surrounding structure is as follows:

$$Q_R = \sigma \epsilon A (T_1^4 - T_2^4) \qquad (6)$$

where
σ = 5.1×10^{-10} watt/°R⁴/ft²
ϵ = emissivity
A = area of radiating body
T_1 = temperature of body - °R
T_2 = temperature of structure - °R

Equation (6) can be factored and rewritten as:

$$Q_R = K (T_1 - T_2) \qquad (7)$$

where

$$K = \sigma \epsilon A (T_1^2 + T_2^2)(T_1 + T_2) \qquad (8)$$

It will be assumed that T_1 and T_2 in (8) do not differ greatly from the RMP structure temperature, T_S. Thus K can be approximated by

$$K \cong 4 \sigma \epsilon A (T_S^3) \qquad (9)$$

The radiated power losses can now be defined as follows:

$$Q_{RB} = K_B (T_B - T_A) \qquad (10)$$

$$Q_{RS} = K_S (T_S - T_A) \qquad (11)$$

where T_A is the cryogenic wall temperature in the chamber. Substituting (10) into (4), and (11) into (5) results in the following:

$$\left(1 + \frac{R_2}{R_1} + R_2 K_B\right) T_B - (R_2 K_B) T_A = \left(\frac{R_2}{R_1}\right) T_A + T_S \qquad (12)$$

and

$$T_B + (R_2 K_S) T_A = (1 + R_2 K_S) T_S - R_2 Q_E \qquad (13)$$

The following values were used to compute the K's:

emissivity, $\epsilon = 1$

RMP structure area, $A_S = 1.15\ ft^2$

gyro bracket area, $A_B = 0.10\ ft^2$

These result in the following:

$$K_B = (0.204 \times 10^{-9})\, T_S^3$$
$$K_S = (0.234 \times 10^{-8})\, T_S^3$$

A computer program was generated to solve (12) and (13) for T_B and T_A at various values of T_S, and to then solve (1) for Q_G and (10) for Q_{RB}. Total power was computed from the following:

$$Q_{TOTAL} = Q_G + Q_E \qquad (14)$$

Gyro heater power was computed by:

$$Q_{HEATER} = Q_G - Q_M \qquad (15)$$

where Q_M is the gyro spin motor power.

A total of four computer runs were performed. For all runs, the following parameters were as given below:

$$Q_E = 2.0 \text{ watts}$$
$$Q_M = 3.0 \text{ watts}$$
$$T_G = 623°R\ (163°F)$$

For the first three runs, the thermal resistances were varied as follows:

	Run #1	Run #2	Run #3	
R_1 =	7	7	5	°F/watt
R_2 =	7	5	7	°F/watt

The total input power in run #3 most nearly matched the levels observed in the T-V chamber at NASA/GSFC. The results of this run are plotted in figure 1.

It is anticipated that in the spacecraft, Q_{RB} will be negligible due to the shielding of the structure. To simulate this condition, a fourth computer run was performed identical to the third except that K_B was set equal to zero. The results are plotted in figure 2.

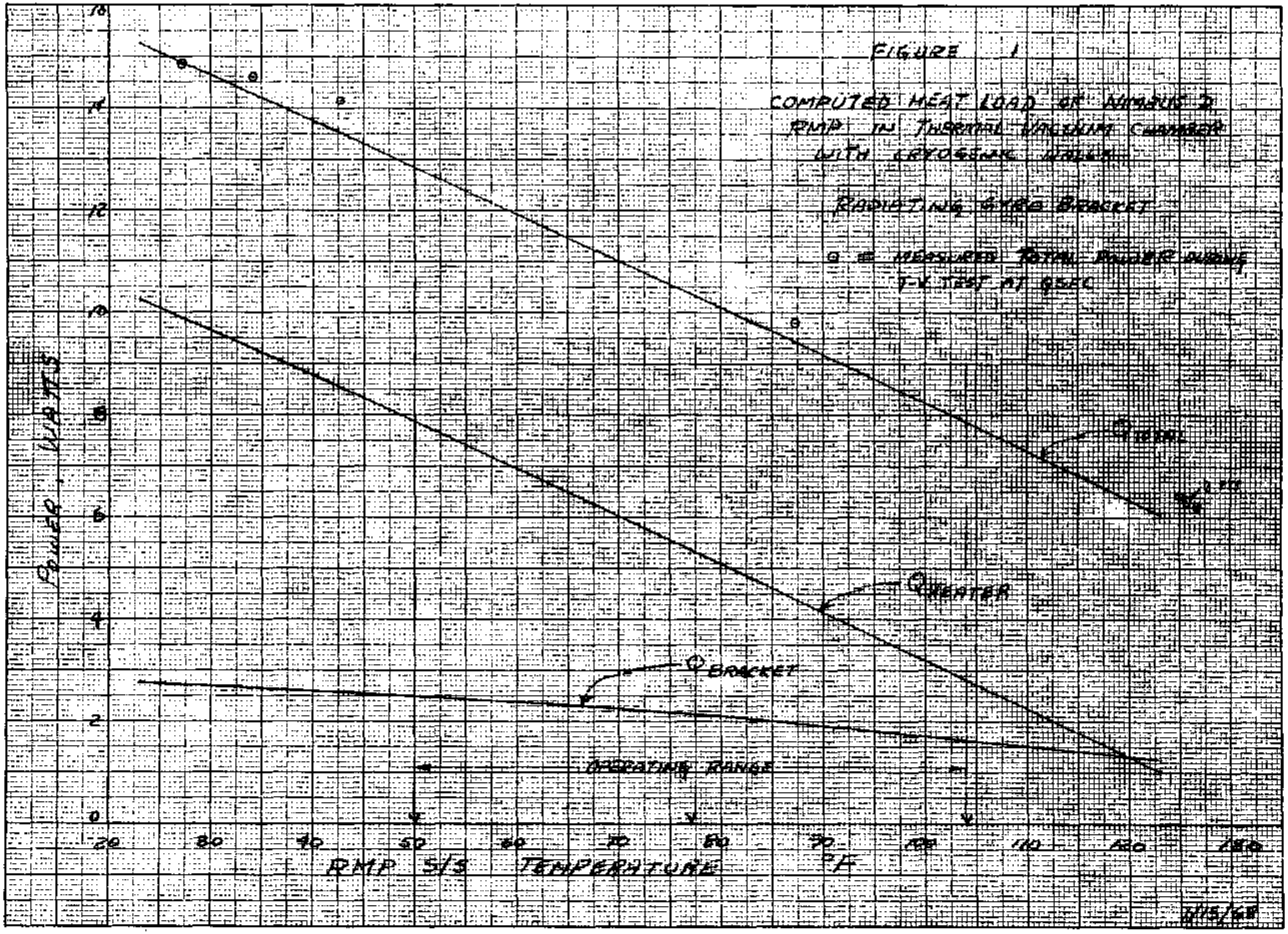


FIGURE 1
COMPUTED HEAT LOAD OF NIMBUS 2 RMP IN THERMAL VACUUM CHAMBER WITH CRYOGENIC WALLS
RADIATING GYRO BRACKET
○ = MEASURED TOTAL POWER DURING T-V TEST AT GSFC
Q_{TOTAL}
Q_{HEATER}
$Q_{BRACKET}$
OPERATING RANGE
POWER, WATTS
0
2
4
6
8
10
12
14
16
20
30
40
50
60
70
80
90
100
110
120
130
RMP S/S TEMPERATURE °F

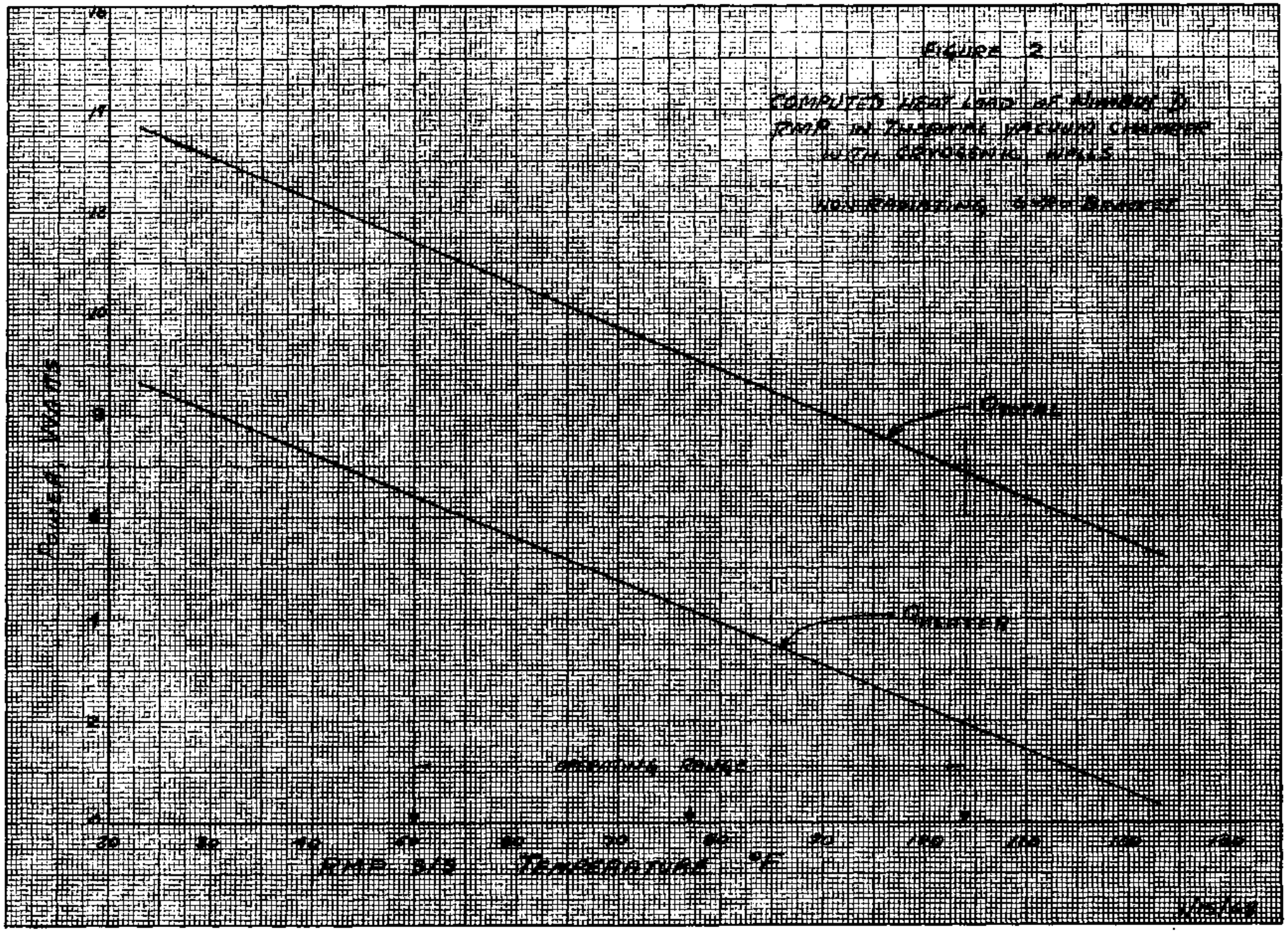


FIGURE 2
RMP IN THERMAL VACUUM CHAMBER
WITH CRYOGENIC WALLS
POWER, WATTS
RMP S/S TEMPERATURE °F
OPERATING RANGE

Appendix IV

REVIEW OF FAILURE REPORT ON KEARFOTT GYRO S/N 1

REVIEW OF FAILURE REPORT

ON

KEARFOTT GYRO C702564015-1 S/N 1

PREPARED BY: H. Wendel 1/8/70
H. Wendel

A. Squillante 1/8/70
A. Squillante

APPROVED BY: R. Domini 1/8/70
R. Domini
ESH - Department 4222

INTRODUCTION:

The general wording and conclusions drawn in the failure analysis are acceptable to Sperry; however, some detailed points are raised that require clarification and/or further analysis or supporting data.

Point 1 - In reference to a black tar-like substance found on the +6A balls and retainer. Was this material analyzed and if so, what were the results? If not analyzed, can this analysis be performed and the results be made known and included in this FA report?

Point II - Regarding the verification of the lubricant failure by Singer-Kearfott motor engineering. What type of analysis and/or tests were run to verify this lubricant failure by motor engineering?

Point III - Regarding mention of "rare occasions" of lubricant breakdown. Are any statistics available on the frequency of this type of breakdown and what are they,

Point IV - What effort could the Nimbus Flight level vibration have toward precipitation of this failure? Add Singer-Kearfott comments.

CONCLUSION:

The purpose of the teardown and subsequent failure analysis funded by Sperry was to gain insight into the type of failure and preventative action to be taken. The conclusion made by Singer-Kearfott that no recommendations be made for any changes to be incorporated as a result of this failure are not acceptable to Sperry, as stated. Singer-Kearfott must supply some failure history or statistical data to support their position, in that this is an infrequent and unexplained state-of-the-art failure.

B

SINGER - GENERAL PRECISION INCORPORATED

KEARFOTT DIVISION

ROUGH DRAFT

FAILURE ANALYSIS REPORT

C702564015-1

FLOATED RATE INTEGRATING GYROSCOPE

Serial Number 1

Prepared By: Edward A. Albuquerque Jr.
Edward A. Albuquerque, Jr.
Group Leader, Quality Assurance

Approved By: M. J. D'Addato
M.J. D'Addato
Section Head, Quality Assurance

H I S T O R Y

S/N #1 is one of four C702564015 Gyros which were built during the latter part of 1967 and the beginning of 1968 for the Sperry Company for use in the Nimbus Weather Satellites. During this same time period, Alpha Series Gyros were also being manufactured for several other programs. This unit was assembled, submitted to final acceptance testing, and was subsequently shipped on October 15, 1967. See Figure I and the left portion of Figure III for the pre-ship data summaries of S/N #1.

No information concerning Gyro field performance was received by Kearfott until March of 1969. At this time, a communication was received from the Sperry Company indicating that S/N #1 was in a Nimbus System but not performing well. The gyro anomalies noted during Sperry testing were:

- g - Sensitive drift rate shifts of up to 1 degree per hour.
- low frequency oscillations (1 1/2 hz.) observed in the Nimbus rate loop output.
- Motor rundown time changes after the thermal vacuum test -- approximately a one minute loss in total RDT and a 30-0 RDT which varied between 24 and 49 seconds with one low reading of 16 seconds.

The Gyro motor had seen approximately 1250 hours and Sperry stated that this Gyro was an "extremely noisy" one at this time. See figure II for a synopsis of the motor data taken in the field on S/N 1.

Two Kearfott personnel visited the NASA-Goddard facility at Greenbelt, Maryland on March 17, 1969 to discuss this Gyroscope with representatives of NASA, Sperry, and General Electric - Pittsfield. The performance data from the Nimbus System containing this Gyro and from another system were reviewed at this time. The 1½ Hertz Oscillation was described as being related to motor "hunt frequency" and examination of test data from the "good" system indicated that it was also present there. This low frequency phenomenon was not affecting system performance. The combination of g-sensitive drift level shifts and decreasing run down times were indicative of possible motor degradation. However, the gyro was still performing just within specification limits when measured at the gyro level. NASA felt that it would be impractical at this time to tear down the unit and possibly find nothing. It was concluded that NASA would remove S/N 1 from their system and perform a life test on the instrument, checking its performance periodically. This life test was stopped after several days and the unit was returned to Kearfott on March 29, 1969 due to continued poor performance. Verification testing commenced on March 31st and was concluded on April 14, 1969. Figure III presents a summary of all data taken at Kearfott. The Gyro was torn down April 17, 1969 in the presence of Kearfott Quality Assurance only and the motor and float assemblies were disassembled on April 18, 1969 with representatives of NASA, Sperry, Kearfott E & D, Operations, and Quality in attendance.

A N A L Y S I S

A review of motor, motor/float, and gyro assembly build records, life history data, and rejection history summaries was performed and no serious problems and/or failures had been encountered during the assembly and test of C702564015 S/N 1. Total motor and motor float time before gyro build was approximately 428 hours and total gyro running time at shipment was 179 hours. Total motor RDT and 30-0 RDT were consistently in the area of 300 seconds and 50 seconds respectively. The 1 sigma value of random drift for the Input Axis Vertical position was 0.002 degrees/hour/hour at final acceptance test (see Figure I and the left side of Figure III for pre-ship data). All pre-ship data is indicative of a reliable gyro whose stability is similar in quality to that of alpha units in production.

Figure II is the tabulation of data which was presented by Sperry to Kearfott and represents the significant spin motor data which was recorded in the interval of October 15, 1967 and March 14, 1969. After several months of performance which is comparable to Kearfott pre-ship motor data, the total RDT and 30'-0 RDT change significantly. The gyroscope was exposed to a thermal vacuum test which consisted of 13 days of continuous running at 165°F and 0 psia. During this interval no motor data was recorded. At the completion of the thermal vacuum exposure, however, the total RDT changed from 252 seconds to 185 seconds and the 30-0 RDT changed from 56 seconds to 42 seconds. From this point (January, 1968) until March, 1969 the data is indicative of a gradual degradation in motor performance. The total RDT gradually decreased to a value of 145 seconds and the 30-0 RDT varied somewhat erratically between a high of 49 seconds and a low value of 16 seconds.

Gyro verification testing at Kearfott consisted of 2 complete ATP's, 10 successive motor performance checks, and then two additional ATP's. During one of the latter ATP's, the gyro was positioned OAH IA Up and an extended random drift test with a motor jag recording of the spin motor "B" phase current was performed. A review of the Kearfott verification data in Figurés III and IV indicates the following:

1. All Gyro performance data is in specification except for the IAV random drift 1 sigma value of 0.061 degrees/hour/hour from April 3, 1969 -- Specification is 0.05 degrees/hour/hour maximum.

2. The comparison of gyro drift with motor current jag reveals exact correlation; i.e., a motor current jag produces a gyro drift level change. After several hours of running, the jag disappears and the unit stabilizes.

3. The total RDT varies from 314 seconds to 187 seconds. The largest change in total RDT (228 seconds to 187 seconds) occurred after the gyro had not been tested for $1\frac{1}{2}$ weeks. In addition, the smallest change occurred when the unit was run continuously.

4. The 30-0 RDT varied irregularly between 32 seconds and 52 seconds. The value at gyro shipment was 56.1 seconds.

5. The test verification does not agree directly with the Sperry data. Their submitted data sheet indicates a gradual degradation in both rundown terms whereas the Kearfott data suggests a more erratic performance which is dependent mostly upon the amount of continuous running time prior to data acquisition.

To summarize the analysis of data, the verification tests at Kearfott essentially substantiated Sperry's complaint of possible motor degradation. The gyro was subsequently dispositioned for teardown. Gyro teardown revealed no out of specification conditions. The disassembly of the motor and float indicated that no oil sling or foreign material was present as determined by 40 power observation. Subsequently the stator, shaft, and bearing assembly was taken apart. The gyro motor bearing inner race, balls, retainer, and outer race from the -SA side displayed no discrepancies. However, the components from the +SA side exhibited lubricant breakdown and impending bearing failure. A black tar-like substance was found on the +SA balls and retainer. Pictures were taken of these components and are attached to this report. The lubricant failure was verified by Singer-Kearfott motor engineering.

C O N C L U S I O N & R E C O M M E N D A T I O N S

The out of specification random drift value and appraent motor degradation as evidenced by erratic and diminishing total RDT and 30-0 RDT were caused by a lubricant breakdown within the +SA spin motor bearing. The exact cause for this lubricant failure could not be determined. This type of breakdown occurs on very rare occasions and, with Kearfott's present tried and proven method of motor assembly and testing, cases of this nature are most infrequent and random in nature. The Alpha II motor design has proven itself in space on several programs such as previous Nimbus launches, Lunar Orbiter, Mariner, and OAO. All of these programs utilized a motor design identical to S/N 1 and were all quite successful. Running time in excess of 18,000 hours was measured on the Alpha II gyro in Nimbus C. The only other known Alpha II field failure occurred when a gyro was centrifuged with the motor off causing the gyro motor bearings to become brinelled.

It is Kearfott's considered opinion that this failure was due neither to a design defect nor to a workmanship error, but rather that this is one of those unexplained state-of-the-art failures which randomly occur. All in-process inspection, build, and test procedures are deemed to be adequately stringent for preventing defects of this nature to be experienced in the field. There will be no recommendations made for any changes to be incorporated as a result of this failure.

FIGURE I

	DATE F.T. COMPLETED SPECIFICATION	S/N 1 F/N 2036 10/14/67
Transfer Function - MV/MRIA	29.4 ± 24%	30.43
Positive OA Freedom - DEG	2.4 MIN	3.90
Negative OA Freedom - DEG	2.4 MIN	3.90
SG Null - MV	1.0 MAX	0.48
Characteristic Time - MS	6.4 ± 24%	6.676
Nozzle Test		
OA Up, Sum of Spikes 0.25 DEG/HR-DEG/HR	1.0 MAX	0.37
SA Up, Sum of Spikes 0.25 DEG/HR-DEG/HR	1.0 MAX	0.48
OA Down, Sum of Spikes 0.25 DEG/HR/DEG/HR	1.0 MAX	0.37
Elastic Restraints - DEG/HR	0.3 MAX	0.219
Vacuum Warmup Test		
Sensor Resistance at 160°F - OHMS		774.0
Calc. Time to Reach 160°F - MIN		16.9
Actual Time to Reach 160°F - MIN	Calc. Time ± 6	17.0
S.G. Temp at 160°F - DEG F	135°F MIN	140.3
Tumble Test		
MUIA -DEG/HR/G	±1.0 MAX	-.215
MUSA -DEG/HR/G	±1.0 MAX	± .097
Restraints -DEG/HR	±2.0 MAX	± .042
Deviation from Smooth Curve-DEG/HR	0.5 MAX	.160
Random Drift		
OAV 10° - DEG/HR	0.05 MAX	.007
IAV 10° - DEG/HR	0.05 MAX	.002
Ramp Drift Rate - DEG/HR/HR	0.0015 MAX	.000314
Drift Tests		
Cycle A		
TSF -DEG/HR/MA	134 ± 13	131.4
Restraints -DEG/HR	±2.0 MAX	-.032
MUIA -DEG/HR/G	±1.0 MAX	-.263
MUSA -DEG/HR/G	±1.0 MAX	+.014
Cycle B		
TSF -DEG/HR/MA	134 ± 13	131.3
Restraints -DEG/HR	±2.0 MAX	-.003
MUIA -DEG/HR/G	±1.0 MAX	-.250
MUSA -DEG/HR/G	±1.0 MAX	-.004
Cycle C		
TSF -DEG/HR/MA	134 ± 13	131.3
Restraints -DEG/HR	±2.0 MAX	-.055
MUIA -DEG/HR/G	±1.0 MAX	-.230
MUSA -DEG/HR/G	±1.0 MAX	-.001
Drift Rate Shifts		
Restraints Cycle A to B - DEG/HR	0.5 MAX	.029
A to C - DEG/HR	0.5 MAX	.023

		SPECIFICATION	S/N 1
Drift Rate Shifts con't			
MUSA	Cycle A to B - DEG/HR/G	0.5 MAX	.018
	A to C - DEG/HR/G	0.5 MAX	.025
MUIA	Cycle A to B - DEG/HR/G	0.5 MAX	.013
	A to C - DEG/HR/G	0.5 MAX	.033
Motor Characteristics			
RRFT 30-0 HZ -SEC	(Motor Spec-Ref 40-60 Sec)		56.10
Starting Current -MA		154 MAX	105
Running Current -MA		134 MAX	94
Running Power -WATTS		3.5 MAX	2.28
Rate Mode Output Signal Noise - DEG/HR		0.4 MAX PEAK TO PEAK	0.174

PS:mb
5/20/69

SPERRY GYROSCOPE DIVISION
Sperry Rand Corporation

To: Mr. R. Domini

FIGURE II

File: 4222

From: T. Wood, X3685, E-6

Date: April 25, 1969

Subject: Kearfott Gyro S/N 1 Rundown History

1. Following is a summary of rundown times of Kearfott gyro S/N 1 in RMP S/N 5 (PRO2).

Date	Rundown Times Total	Rundown Times 30Hz-0	Comments
10-14-67	---	56 sec	Kearfott acceptance data
12-13	4m-20sec	---	Start RMP S/N 5 FAT
12-15	4 - 35	---	
12-18	4 - 20	---	
12-20	4 - 30	---	Complete Initial FAT
12-27	4 - 45	---	Complete Humidity Test
12-28	4 - 30	---	
12-29	4 - 40	---	
1-3-68	4 - 12	---	Z Axis Vibration
1-3	4 - 45	---	X Axis Vibration
1-3	4 - 35	---	Y Axis Vibration
1-4	4 - 40	---	
1-8	4 - 20	---	
1-8	4 - 12	---	
1 - 9		---	Start Thermal-Vacuum Test
1-22	3 - 5	---	Complete Thermal-Vacuum Test
1-24	3 - 42	---	
1 - 24	3 - 50	42	Complete Final FAT
2-15	3 - 30	---	Acceptance Test at Sperry
2-15	3 - 23	---	Acceptance Test at Sperry (heater off)
2-23	3 - 11	---	Acceptance Test at GE/VFSTC
2-23	3 - 29	---	Acceptance Test at GE/VFSTC
5-10	3 - 23	36	Special Test at GE/VFSTC
10-30	3 - 53	46	Special Test at GE/VFSTC
10-30	3 - 40	44	Special Test at GE/VFSTC
10-30	3 - 45	49	Special Test at GE/VFSTC
3-5-69	2 - 38	24	Special Tests at GE/VFSTC
3-5	2 - 28	16	Special Tests at GE/VFSTC
3-10	2 - 43	27	Tests at Sperry
3-10	2 - 41	27	Tests at Sperry
3-11	2 - 47	27	Tests at Sperry in RMP S/N4
3-14	2 - 25	35	Tests at Sperry
3-20	--	---	Gyro S/N 1 removed from RMP S/N5

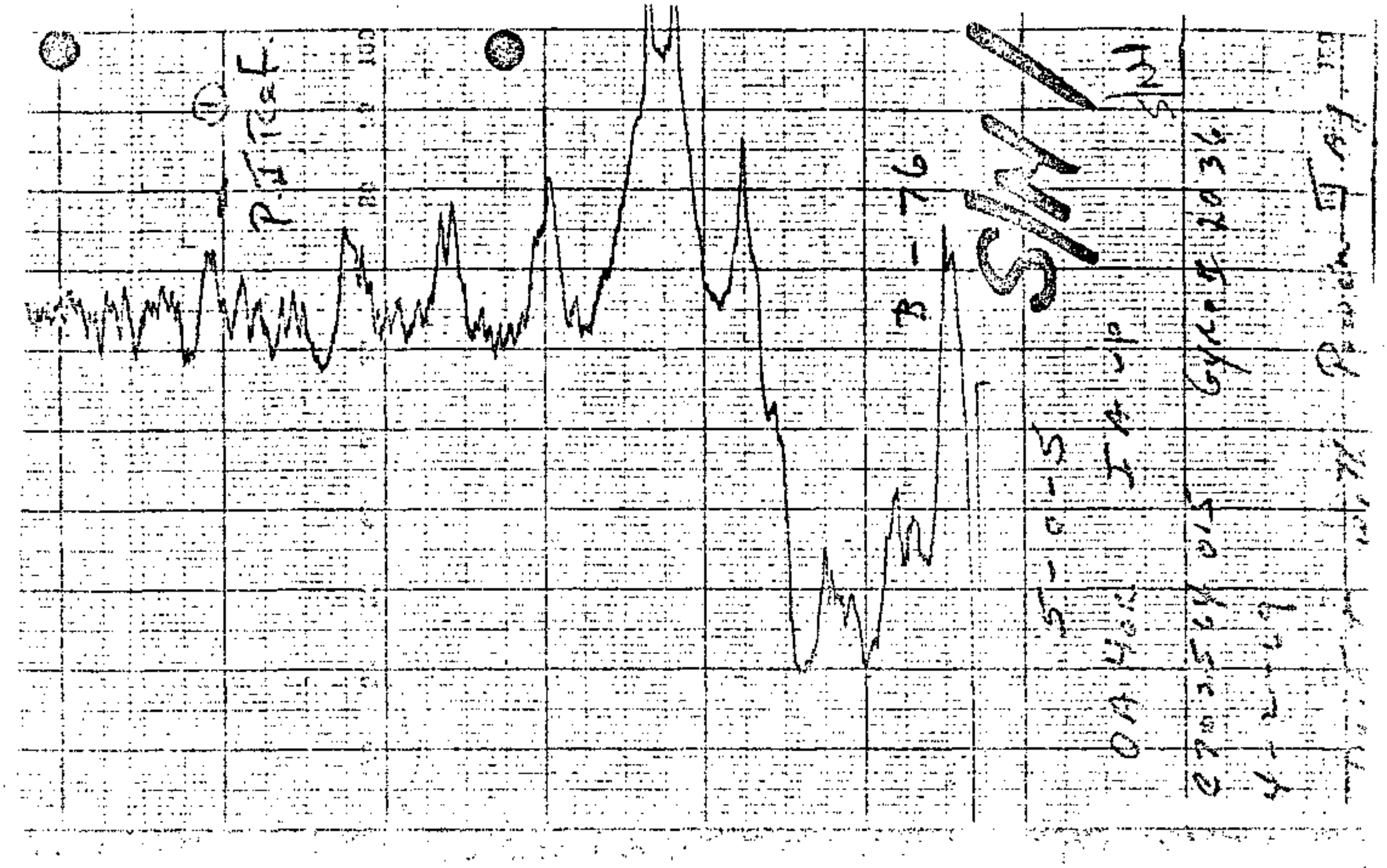
T. Wood 4/21/69
T. Wood

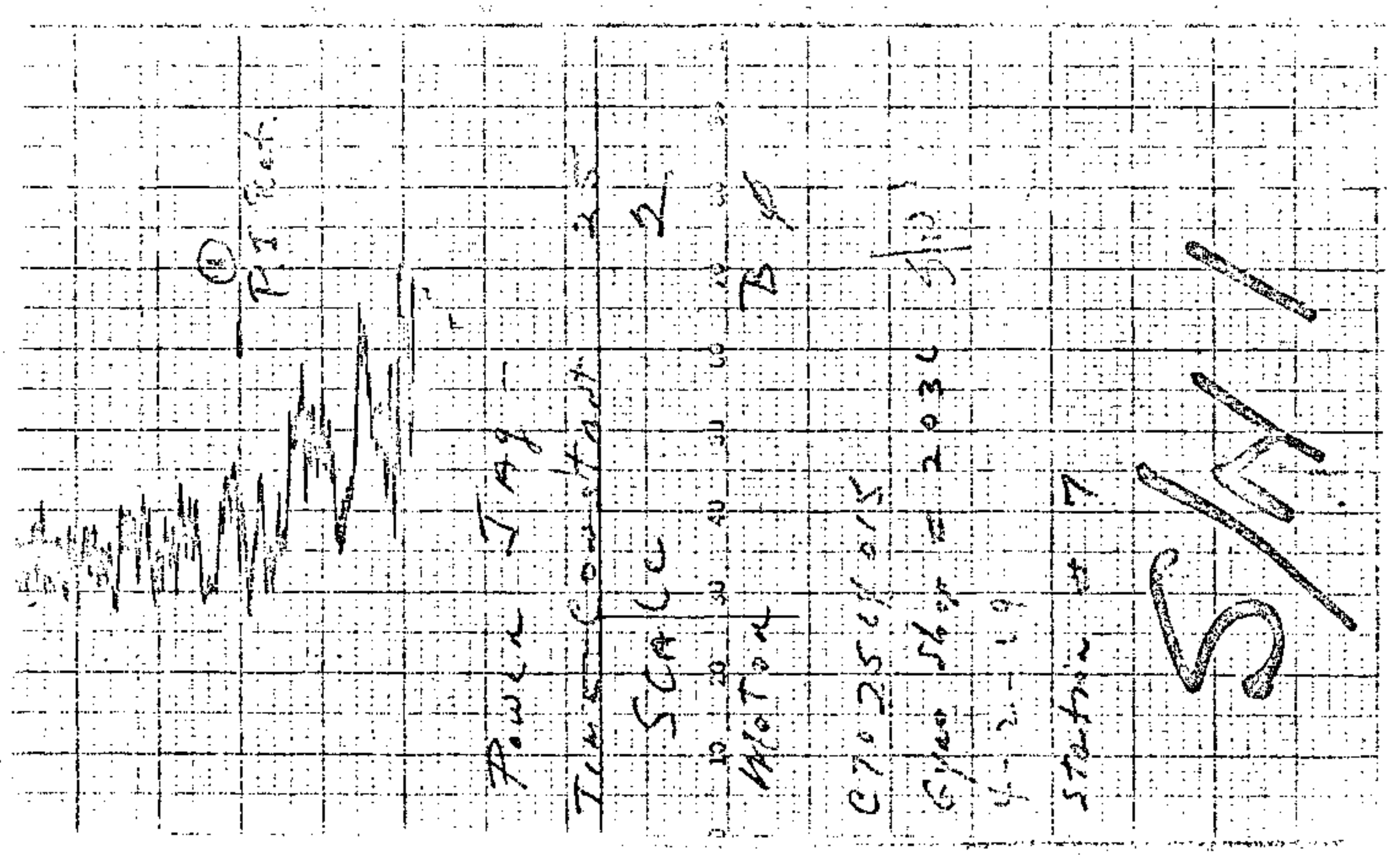
		AS SHIPPED				AS RETURNED			
	DATE	10-2-67	10-7-69	10-8-69	10-9-69	3-31-69	4-1-69	4-1-69	4-2-
	RUN		A	B	C				
S.G. CHAR.	NULL (MV)				0.48	3.8			
	TOTAL STOPS (MV)				320	310			
	S.G S.F (MV/DEG)				41	41			
	GAIN				13.825	12.891			
DRIFT CHAR.	TSF °/HR/ma		.131372	.131331	.131331	.130730	.130650		
	OAV REST (°/HR)		−.032	−.003	−.055	+.068	+.0665		
	MUSA °/HR/G		+.014	−.004	−.001	−.187	−.325		
	MUIA °/HR/G		−.263	−.250	−.230	−.324	−.444		
IAV RANDOM DRIFT	1 σ (°/HR/HR)				.002	.028	.038		
	LENGTH OF RUN				32 MIN.	1 HR.	40 MIN.		
	PEAK TO PEAK (°/HR)				.005	.144	.196		
	JAG AMPLITUDE (mm)				NONE	0.5	1.5		
OAV RAND. DRIFT	1 σ (°/HR/HR)				.007	.007			
	LENGTH OF RUN				36 MIN	1 HR. 17'			
	PEAK TO PEAK (°/HR)				.020	.081			
MOTOR CHAR	MOTOR EXCIT.	1Ø ⊓ 26 V				3Ø ~ 26 V	1Ø ⊓ 28 V.	1Ø ⊓ 28 V	1Ø 2
	SYNC TIME (SEC)	96.42"				54.96"	115.73"	104.94"	10
	400-0	5'06"				4'12"	3'32"	4'21"	4
	400-390 (SEC)	5.26"				3.32"	3.65"	3.71"	3.
	390-400 (SEC)					2.73"	4.10"	4.50"	5.
	400-360 (SEC)	13.68"				14.40"	14.10"	14.00"	1
	360-400 (SEC)	11.10"				8.15"	12.08"	13.29"	1
	30-0 (SEC)	59.40"	55.06"	54.74"	56.16"	38.78"	35.72"	32.31"	5
	START. PWR (WATTS)	2.80 W				3.75 W	2.61 W		2.
	RUN. PWR (WATTS)	2.17 W				2.70 W	2.08 W		2.

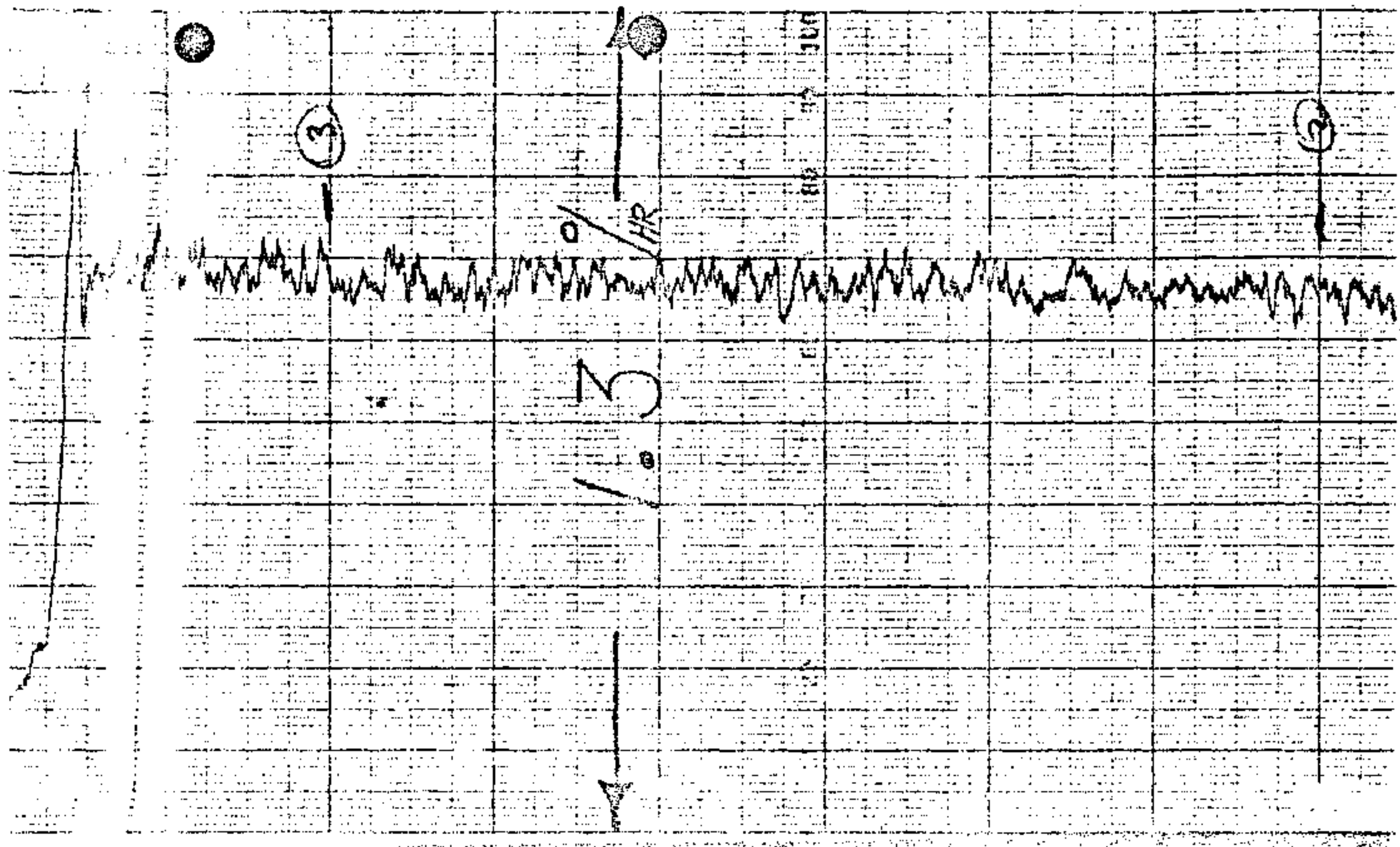
FIGURE III

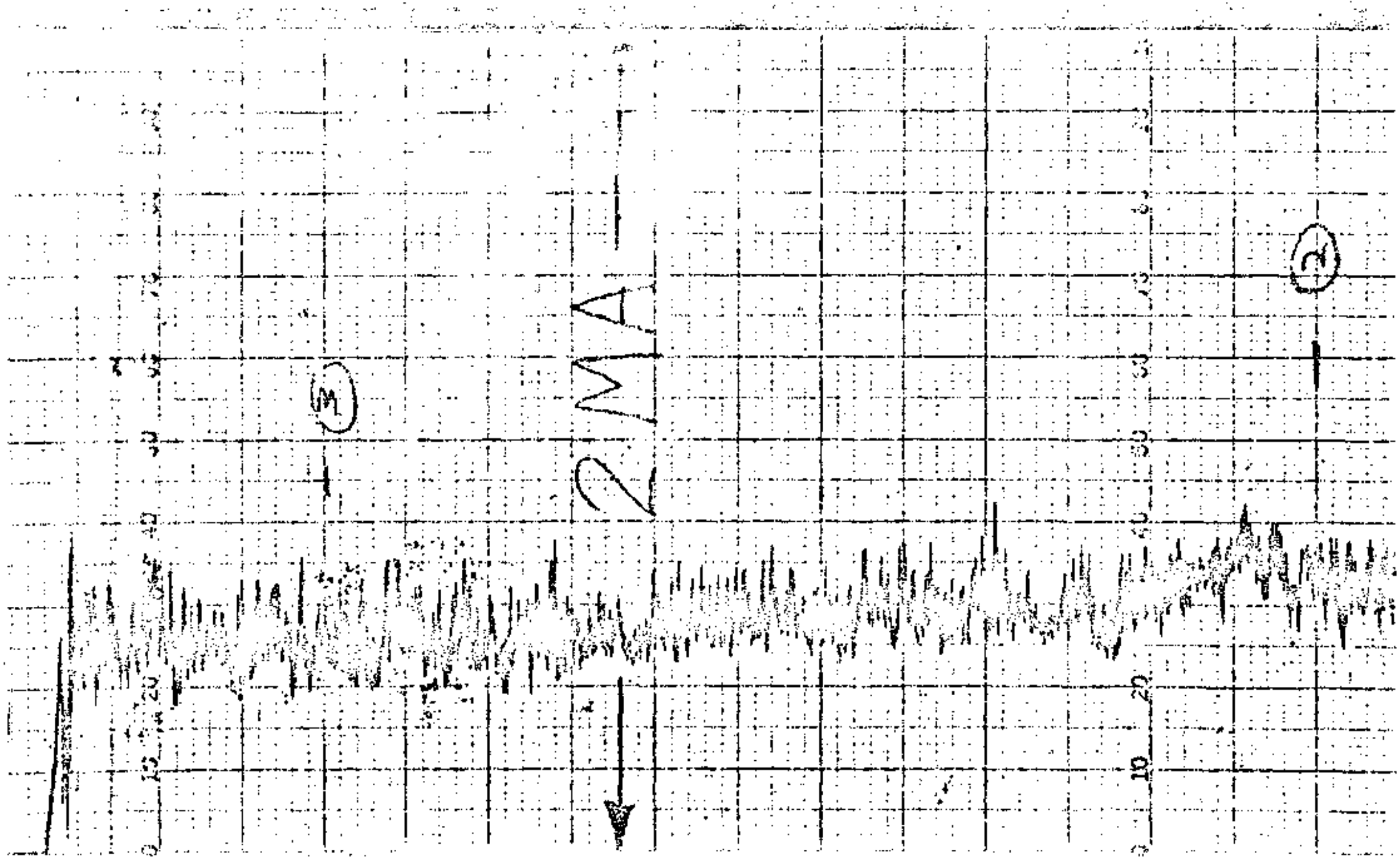
S/N 1   SHOP # 2036

)	4-2-69	4-2-69	4-2-69	4-2-69	4-2-69	4-2-69	4-2-69	4-2-69	4-2-69	4-3-69	4-14-69
										3.5	
										319	
										43.5	
										12.86	
										.130650	.130764
										+.016	+.020
										-.260	-.442
										-.379	-.343
										.061	
										40 MIN.	
										.392	
										1.5	
										.003	
										1 HR	
										.026	
Ω V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	1Ø Ω 28 V	3Ø ~ 26 V	3Ø ~ 26 V
4"	95.49"	100.72"	99.17"	116.74	105.66"	102.39"	109.87"	102.48"	116.35"	56.36"	61.20"
0"	4'51"	4'39"	4'48"	4'54"	4'38"	4'45"	4'49"	4'43"	4'30"	4'48"	3'07"
2"	3.78"	3.29"	3.27"	3.07"	3.88"	3.17"	3.20"	3.46"	3.73"	3.22"	3.24"
0"	4.18"	4.92"	4.64"	4.19"	3.92"	4.70"	4.41"	3.97"	3.82"	3.23"	3.18"
3"	14.71"	12.00"	12.55"	12.21"	15.30"	12.25"	12.66"	14.34"	14.89"	12.66"	12.73"
6"	11.86"	14.24"	13.67"	14.75"	12.22"	14.34"	13.59"	13.97"	11.72"	9.82"	9.32"
2"	50.49"	50.60"	51.18"	51.05"	43.75"	51.40"	51.51"	50.22"	33.61"	47.86"	47.52"
W		2.63 W		2.63 W	2.63 W		2.63 W			3.60 W	3.77 W
W		2.08 W		2.08 W	2.08 W		2.07 W			2.55 W	2.51 W









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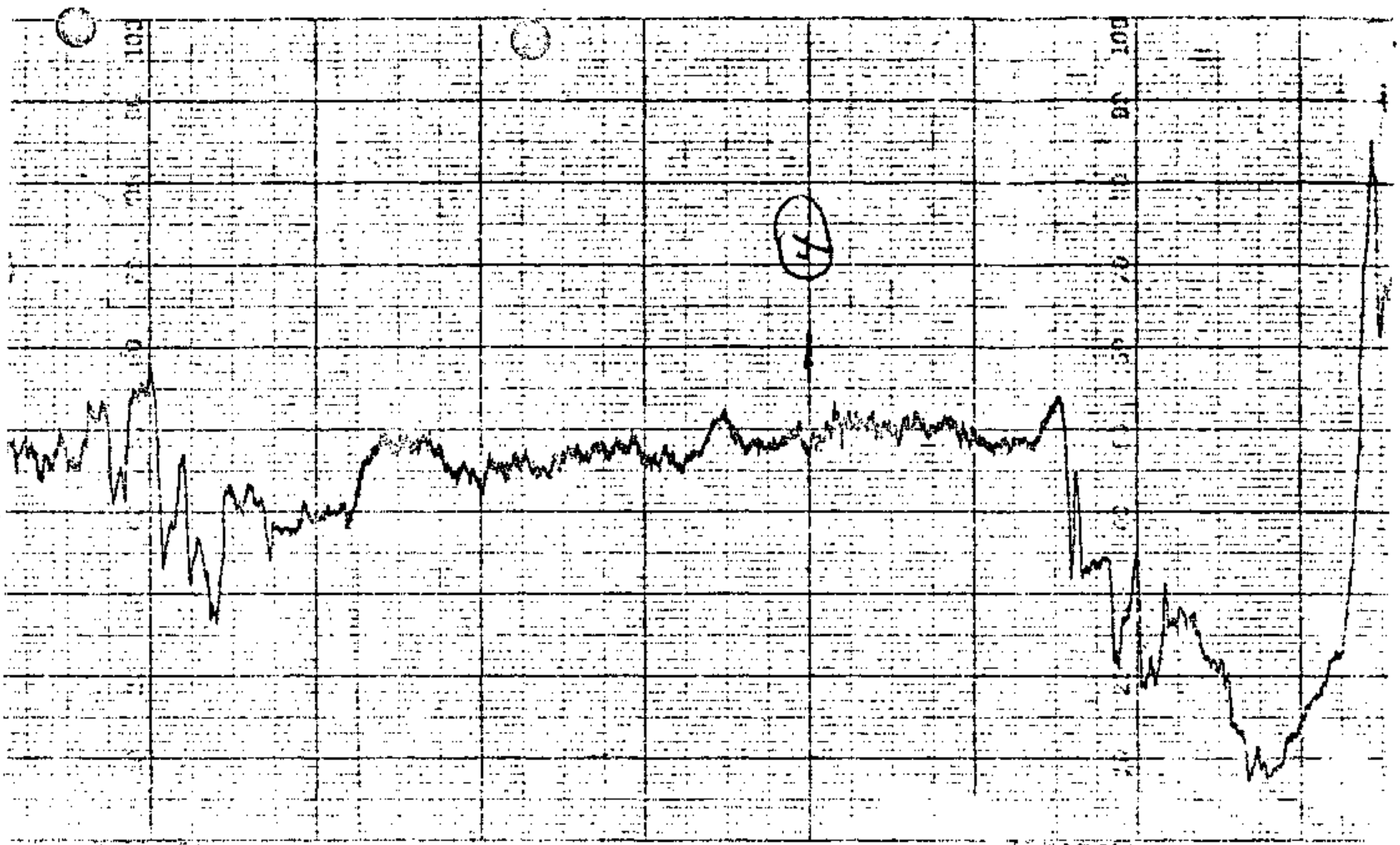
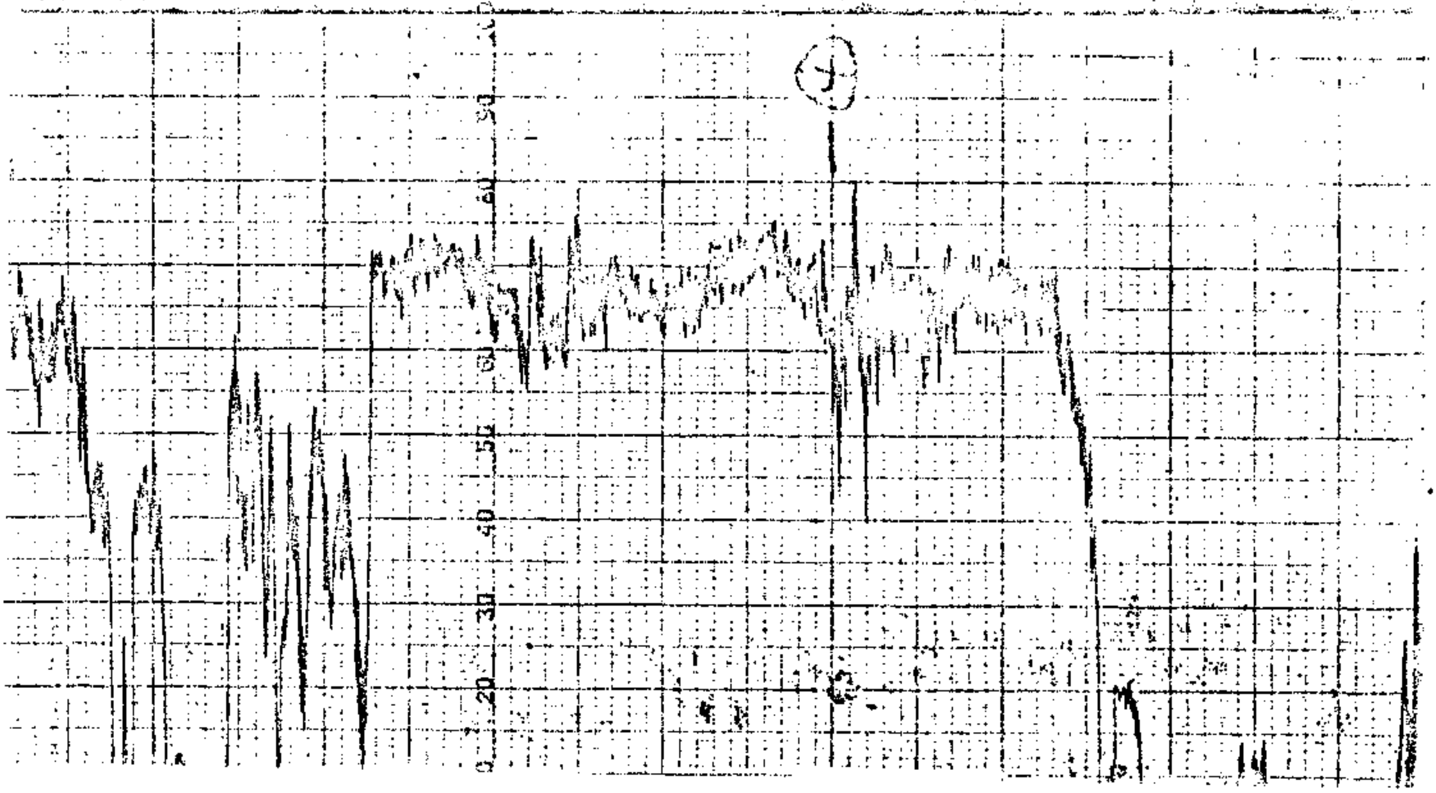
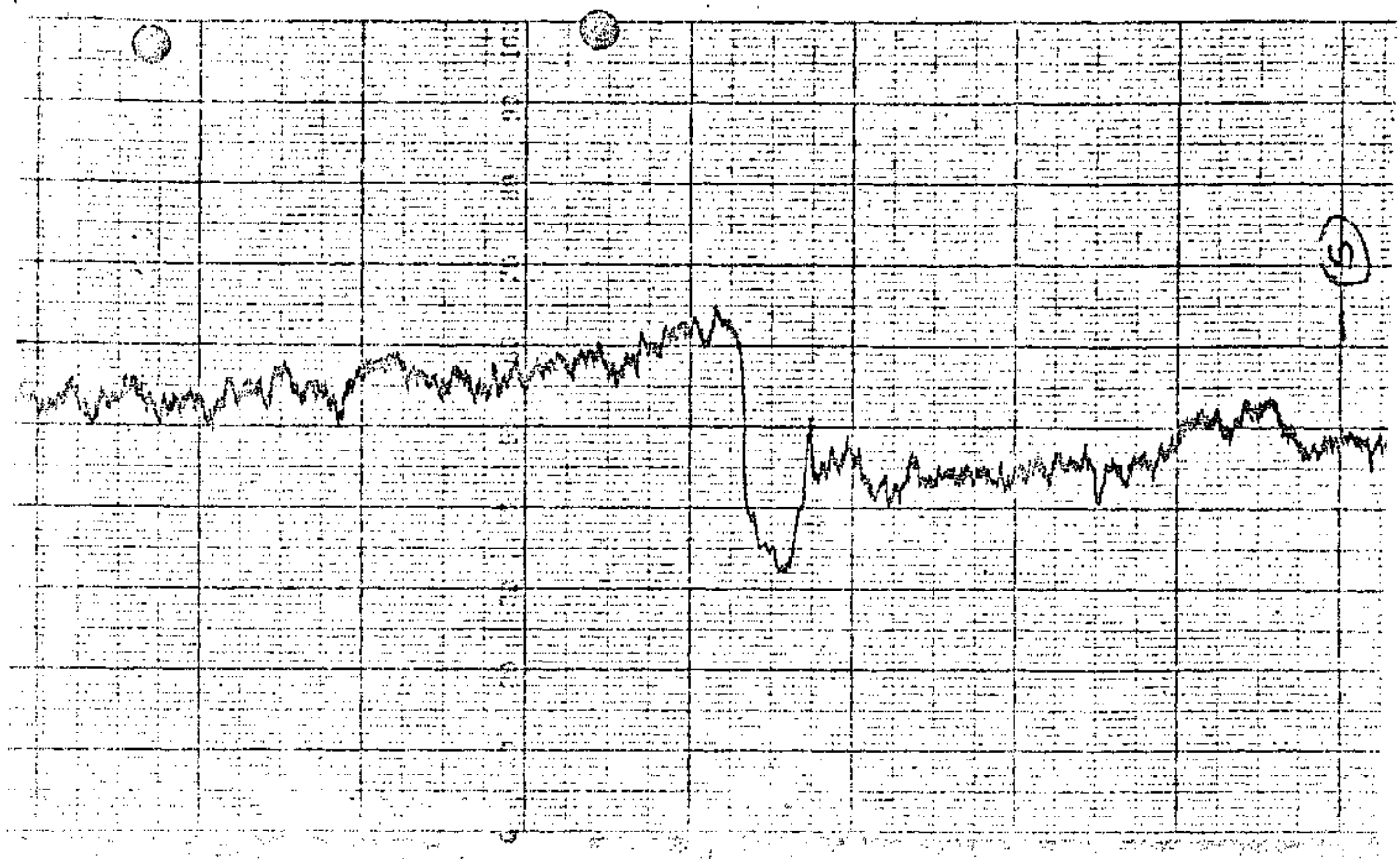
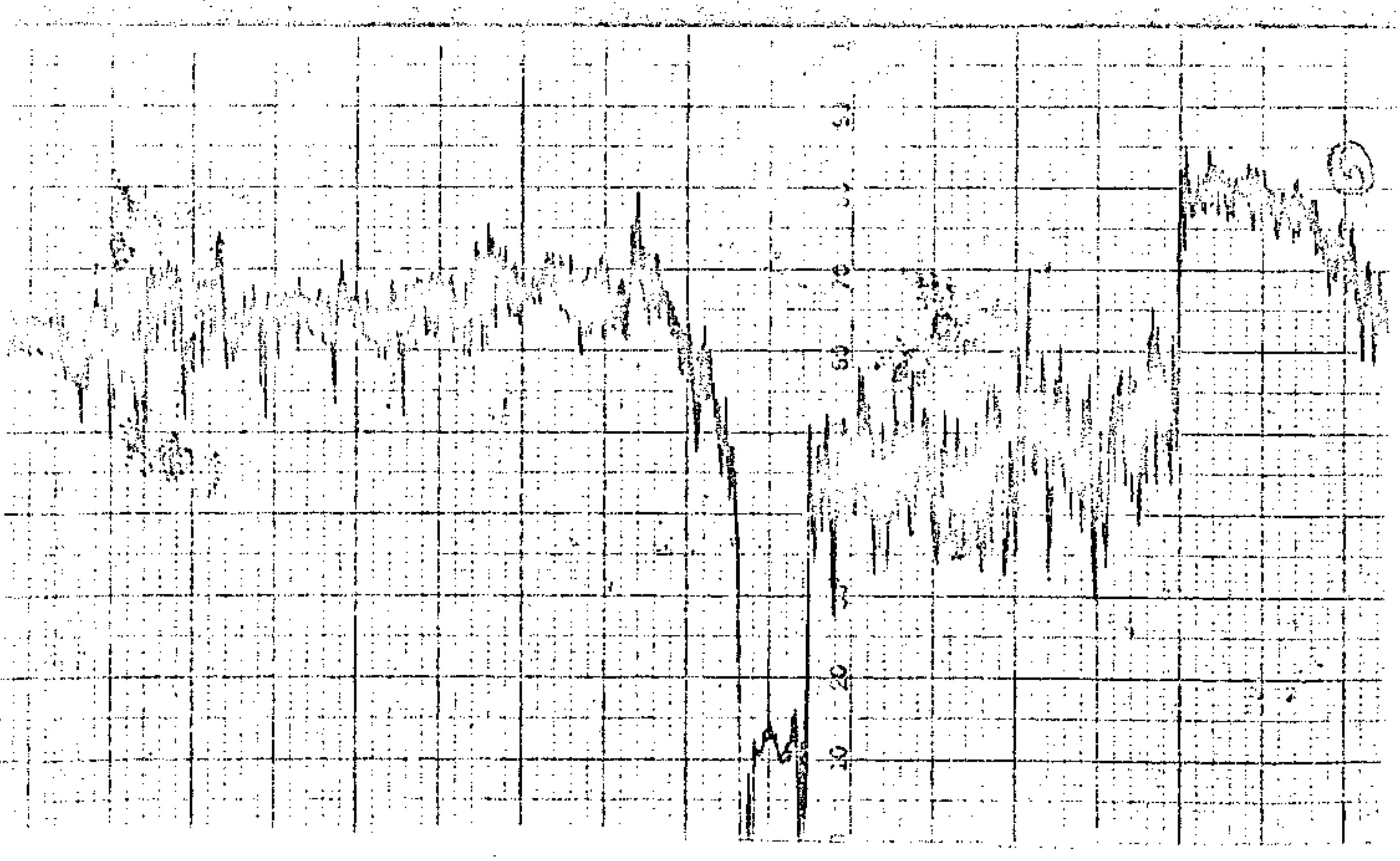
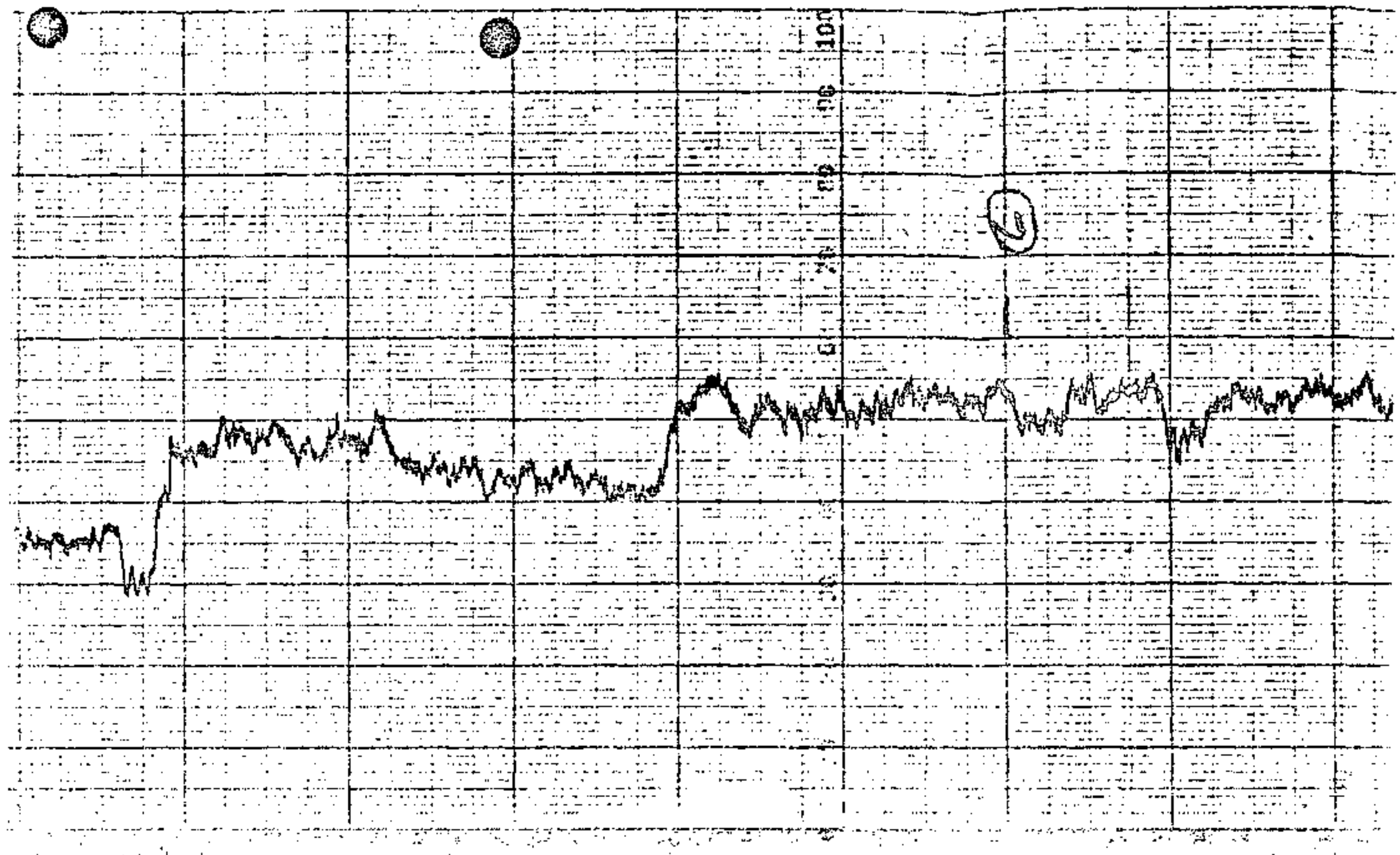
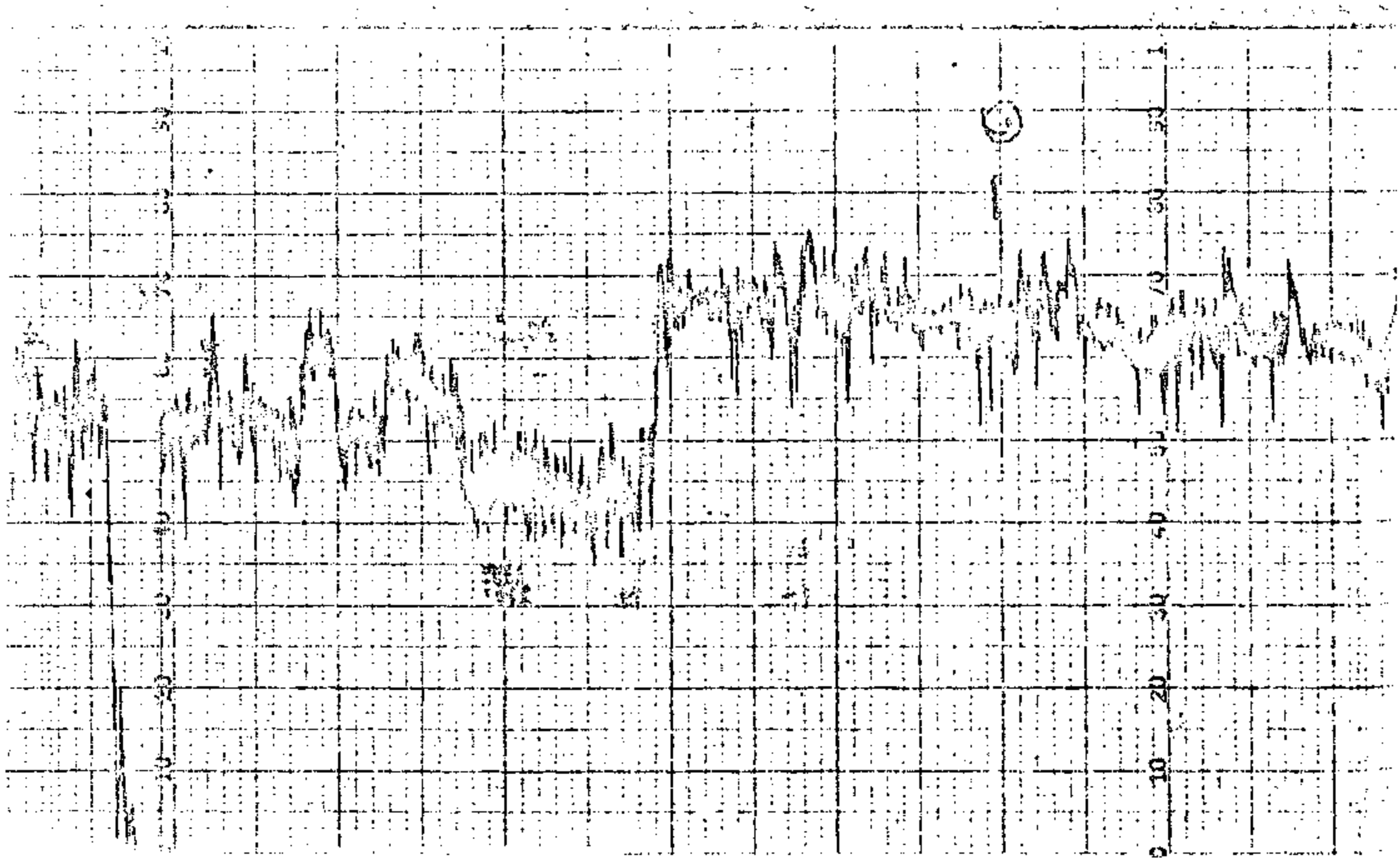


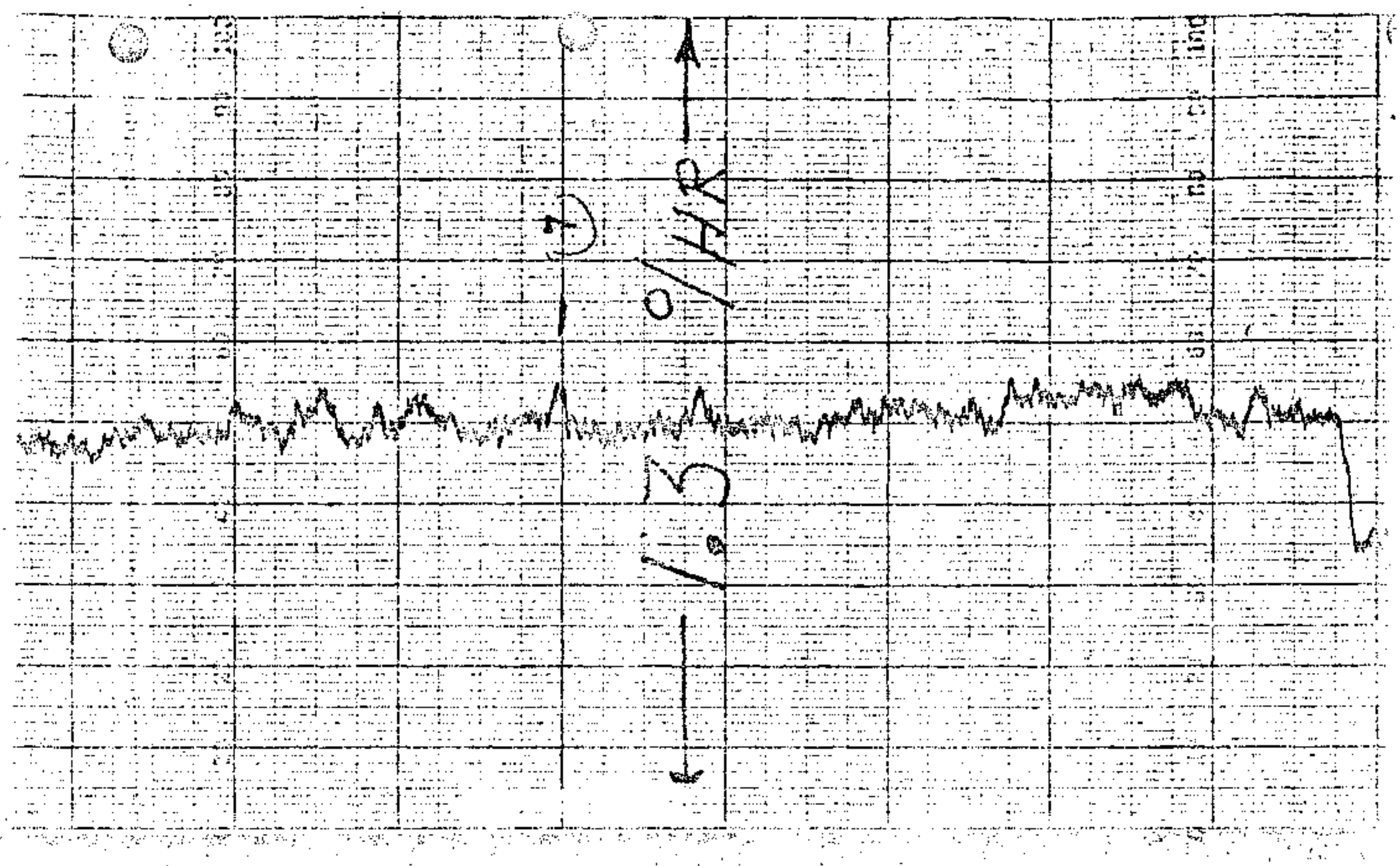


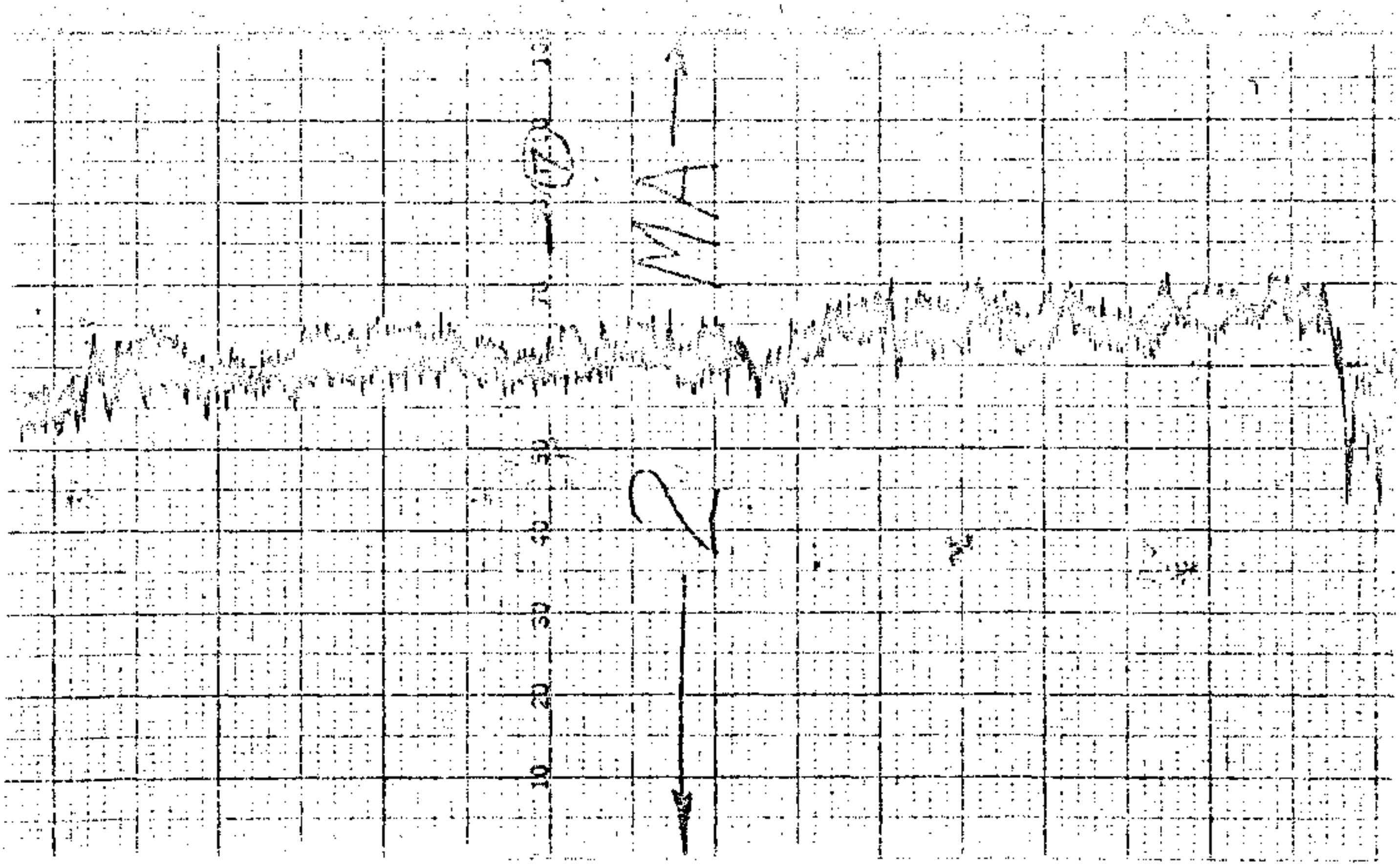









1/3 c/HR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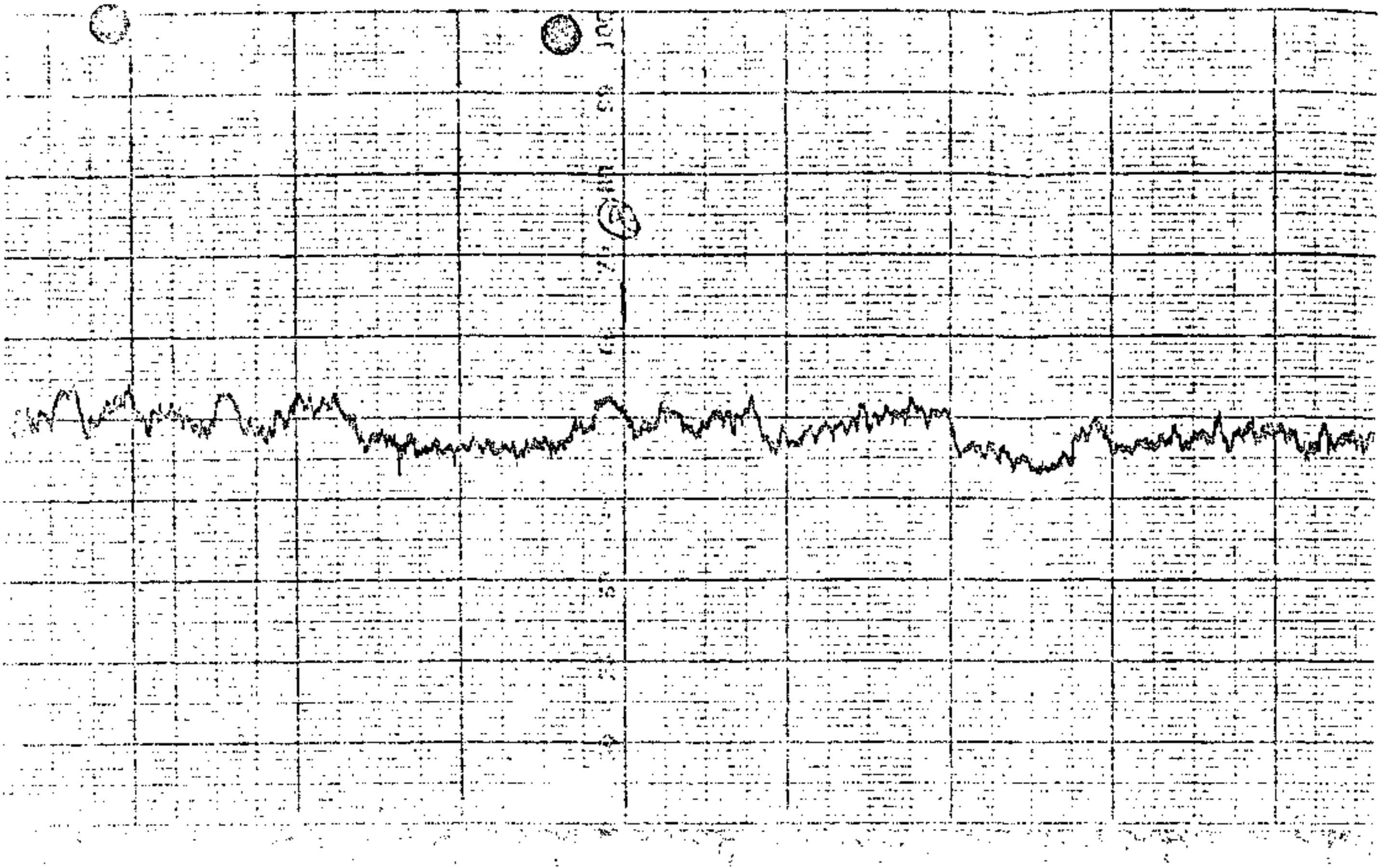
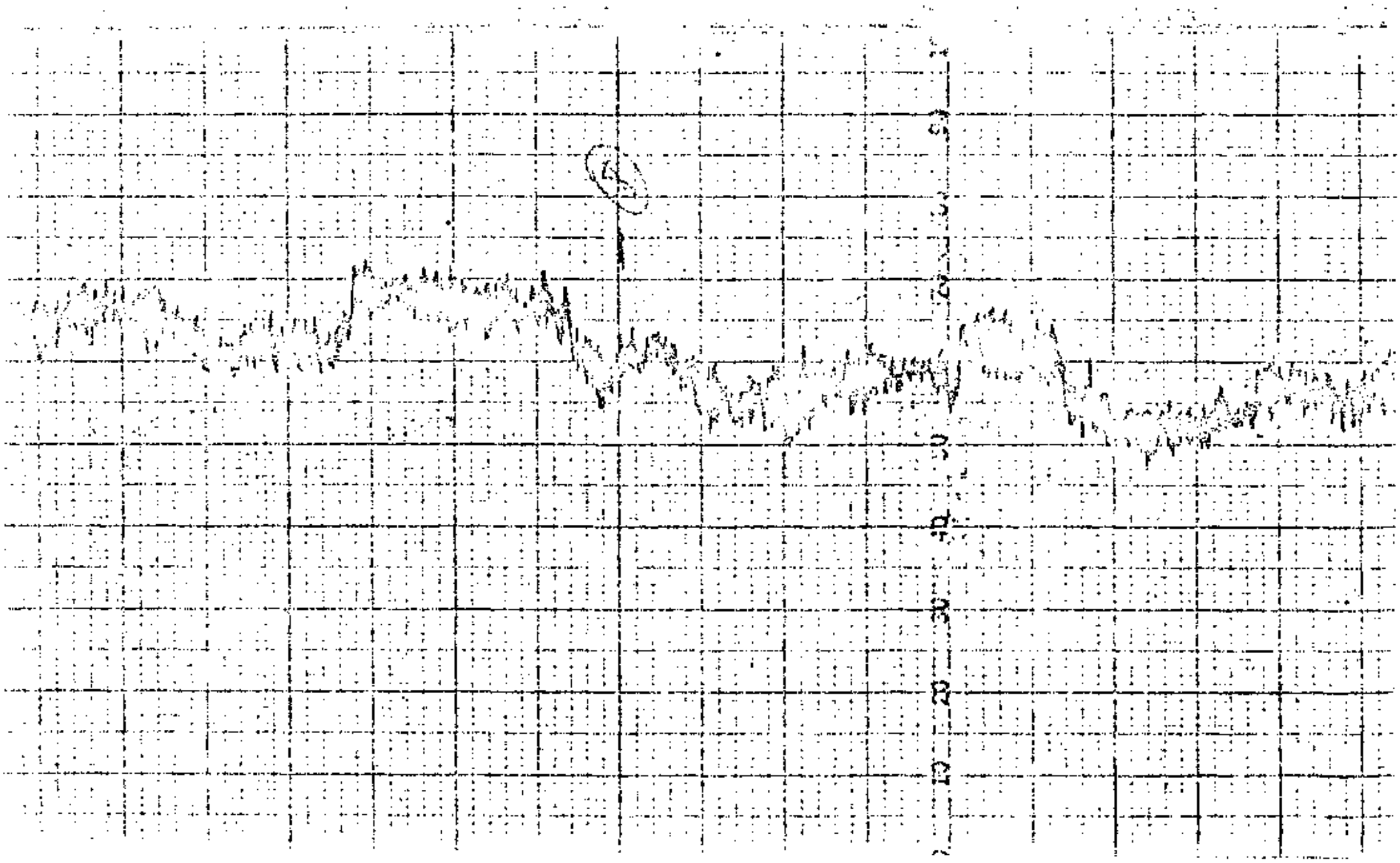
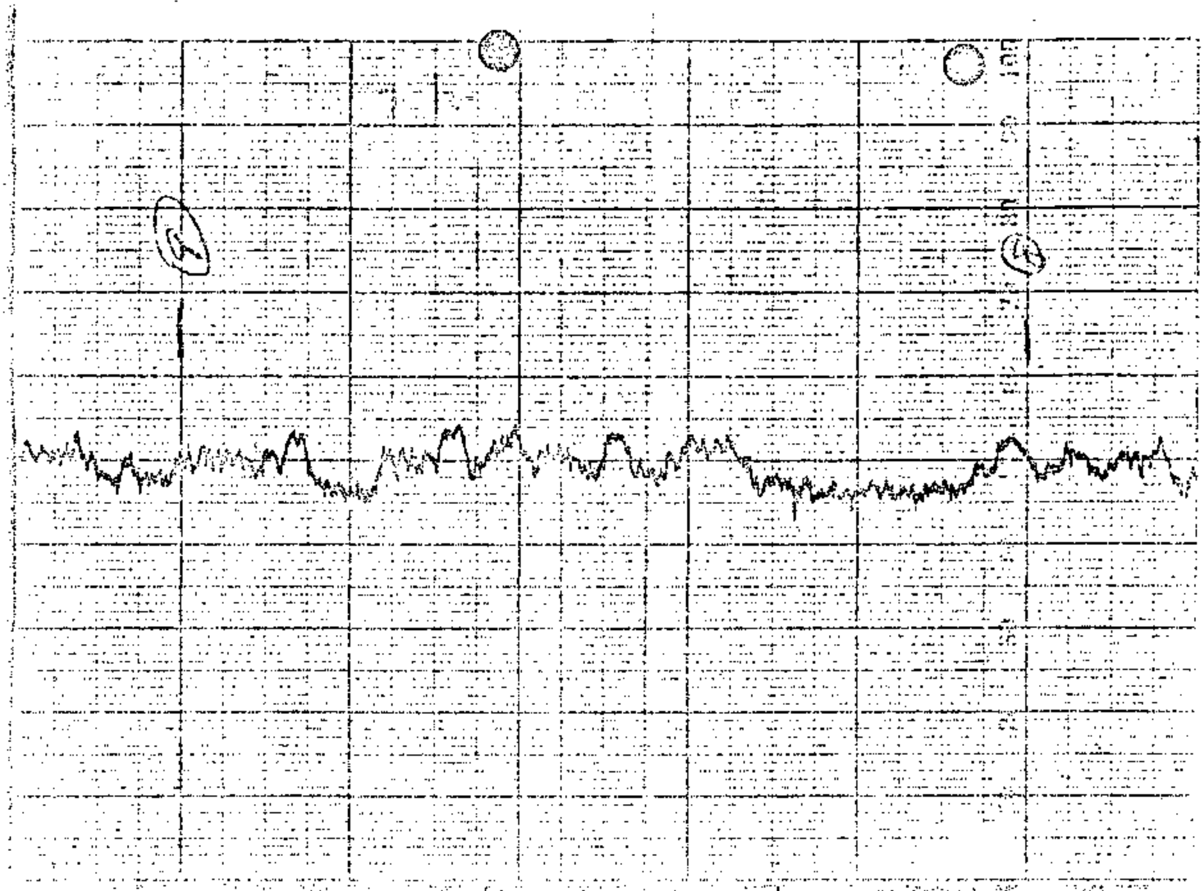
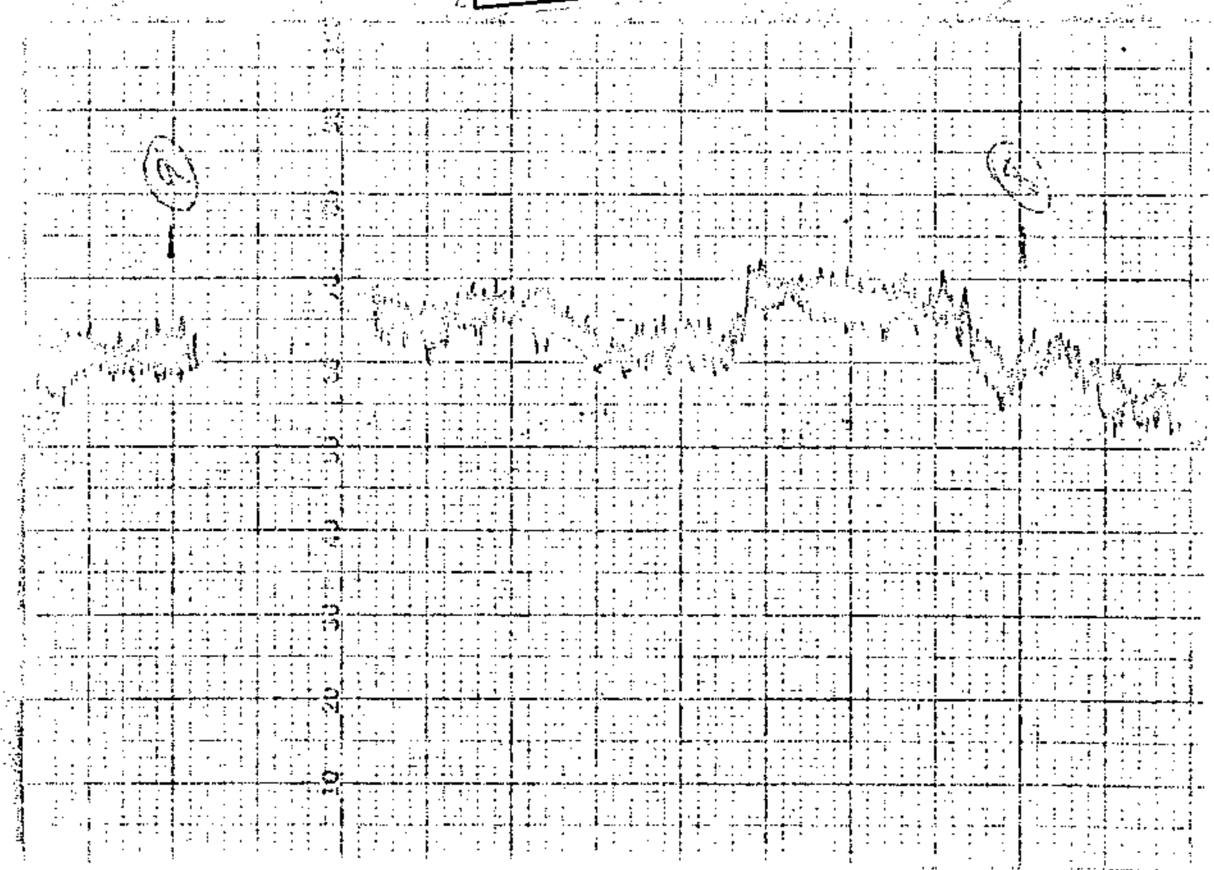








SPERRY GYROSCOPE DIVIS
Sperry Rand Corporation

To: Messrs. A. Blass
H. Diamond
R. Domini
W. Kozma
L. Leshkowich
A. Squillante
T. Wood
F. Yake

THIS COPY FOR

File: 4222

From: H. Wendel

Date: 1 April 1969

Subject: Test of "Temp-Plate" Temperature Indicators

On 3/12/69 the end cover was removed from Kearfott Gyro S/N 1 to permit inspection of the temperature indicator strip. Visual examination by the writer and Mr. F. Yake and M. D. Brooks showed the following:

> The 180°F and the 230°F circles were completely black while the 200°F and 250°F circles showed no sign of discoloration.

Based on these seemingly contradictory findings, it was decided to conduct further tests on the temperature indicator strips. Sperry had purchased from Wm. Wahl Co. a supply of "Temp-Plates" for possible use on our own programs and the selection included the same strips (P/N 240) used on the Kearfott gyros purchased for the Nimbus RMP. Since gyro S/N 1 had undergone Thermal Vacuum tests, a simulation that subjected the temp-plate to both temperature and vacuum was performed. An aluminum block with an internal heating element and bell jar assembly was used to conduct the test. See Figure I.

On 3/12/69 the first "Temp-Plate" sticker was fastened to the aluminum block under the bell jar and evacuated. By means of a variable voltage on the heating element, the block was maintained at a temperature of 165°F and the pressure under the bell jar was less than 50μ of Hg. The next morning visual examination showed that the 180°F and 230°F circles on the sticker were completely blackened while the 200°F and 250° circles remained unchanged.

A second sticker was then placed under the bell jar and a third was placed on the side of the aluminum block exposed to ambient pressure.

Again, examination the next morning showed that the 180°F and 230°F circles on the second strip had become completely blackened It was also noticed that the 180°F circle on the third strip showed some slight speckling. Strip number one was removed and the apparatus was re-evacuated and temperature stabilized at 165°F.

The setup was examined and temperature readings were taken daily until 3/31/69. The 180°F and 230°F circles remained black and the 200°F and 250°F showed no signs of discoloration. However, the 180°F circle on the external strip showed increasing blackness daily until 3/21/69 when it was completely black. All temperature readings taken by thermocouple bridge, however, indicated a steady temperature of 165°F.

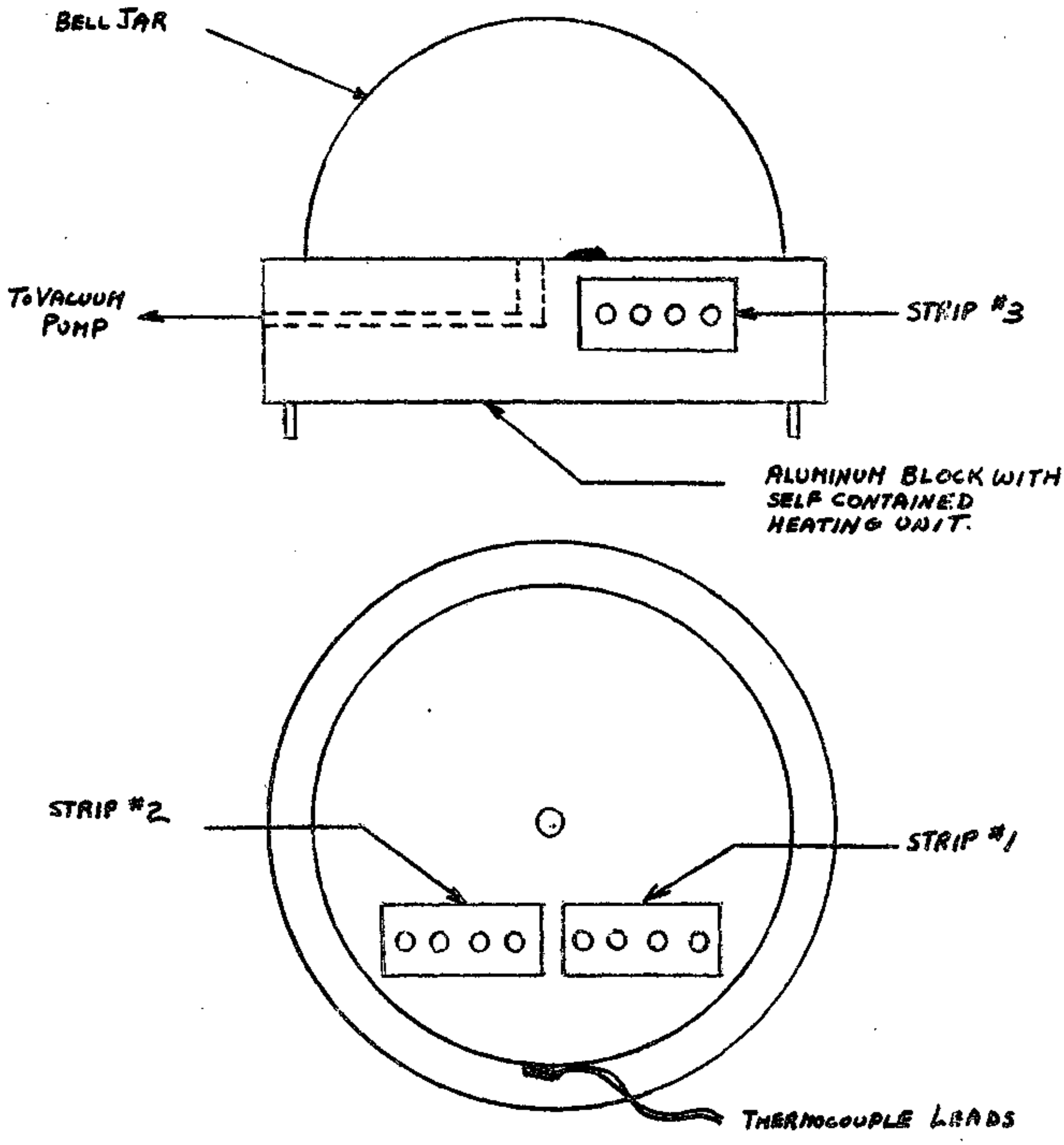
A parallel test subjected a similar "Temp-Plate" strip to conditions of vacuum alone and after 16 days at a pressure less then 10µ of Hg none of the circles showed any sign of discoloration.

Based on these tests, it is Sperry's opinion that the W. Wahl Co. "Temp-Plate" indicators do not provide an accurate record of temperature on the Nimbus/Kearfott gyro and overheat damage claims by the gyro manufacturer must be discounted.

H Wendell 4/2/69

H. Wendell

HW/go



"TEMP-PLATE" INDICATOR TEST SET UP

FIG. I

Appendix V

FAILURE ANALYSIS REPORT ON KEARFOTT GYRO S/N 2

SPERRY GYROSCOPE DIVISION
Sperry Rand Corporation

To: Mr. R. Sanzone

cc: Mr. T. Reilly
Mr. W. O'Flahrety
Mr. F. Yake
Mr. E. Whitcomb

File: 4222

From: R. Domini E6 x1527

Date: 25 October 1968

Subj: Summary of Test, Failure & Teardown of Kearfott Gyro S/N 2

1. Appended to this memo is a copy of the Summary Report of the failure of Kearfott Gyro S/N 2, purchased on PO 317110-82 dated 8/18/67 and returned to Kearfott on D4-411071, dated 6/8/68.

2. As the Summary Report indicates and is also my judgement, the overheat condition was not the cause of failure, but the most likely cause was the vibration test sequence applied to the system and gyro. The Sperry P-Spec. #P1581854 specifies that the unit must meet all the performance parameters after vibration and thermal vacuum.

Kearfott claims the gyro was overheated based on the condition of the temperature indicator strip.

This indicator device was not inspected by Sperry at receipt or during the period the unit was at Sperry and prior to its return. The strip was removed from the gyro prior to Sperry or NASA personnel witnessing the teardown at Kearfott.

3. It is my strong recommendation to negotiate a fair settlement with Kearfott, as there is some <u>uncertainty</u>. However, I do object to the Kearfott statement that

"the overheat occurred at Sperry and the overheat is the cause of failure" . . .

as there is no direct evidence to support this statement. I believe a 25% Sperry - 75% Kearfott share of the responsibility and attendent costs is a reasonable settlement.

R. Domini 10/29/68
R. Domini
Nimbus RMP Program Mgr.

RD:jmc
Encl.

SPERRY GYROSCOPE DIVISION

Sperry Rand Corporation

Failure Analysis Report

Floated Rate Integrating Gyro

Sperry P/N 1200941

Kearfott Gyro Serial #2

23 October 1968

Prepared by: H. Wendel 10/29/68

H. Wendel

Ass't. Eng.-Dept. 4222

Approved by: R. Domini 10/29/68

R. Domini

E.S.H.-Dept. 4222

Summary of Acceptance Test and Teardown

of Kearfott Gyro S/N 2

Kearfott Gyro S/N 2 successfully passed gyroscope acceptance tests and initial RMP F.A.T. tests at Sperry. The system was then sent to NASA/GSFC for Vibration and Thermal Vacuum Tests. It was then returned to Sperry for final F.A.T. testing. The first evidence of the gyro failure appeared during the Final Acceptance Test. The gyro was removed from the system and tested further on a different set of electronics where the failure was confirmed. Details of these tests are contained in CNAP #66 Appended herein.

The gyro was returned to Kearfott for failure analysis and teardown. The failure analysis confirmed a condition of float stiction most likely caused by a particle migrating to a critical fluid gap.

Upon teardown of the gyro, no physical damage to the float or other critical parts was found as would be expected if the unit was overheated. The only significant finding of the teardown was the blackening of the 230°F circle on the temperature indicator. Details of the teardown are contained in CNAP #67 also appended herein.

<u>Sperry Conclusion and Support Information</u>

<u>Conclusion:</u>

The failure of Kearfott Gyro S/N 2 was caused by the presence of a minute particle migrating to a critical fluid gap and not related to an overheat condition if such a condition did actually occur. The migration of the particle was probably caused by the vibration testing of the gyro in RMP S/N 6.

<u>Support Information:</u>

1. An overheat condition should have caused damage to sensitive float bellows, and/or suspension parts. No damage of this type was found during the teardown.

2. Tests of the Sperry Over-Temperature Safety Switch installed in the gyro show that the maximum operating temperature of the gyro could not have exceeded 182°F. This was determined by testing the actual switch used on Kearfott Gyro S/N 2.

3. A review of Test and Grooming procedures confirmed that the Gyro and Gyro Assembly is never subjected to an ambient temperature greater than 180°F during any assembly or test procedure. 180°F is the upper storage temperature limit.

4. The temperature indicator was not inspected by Sperry Incoming Inspection as it is internal to the gyro case, and its condition when the unit was delivered to Sperry is in doubt.

5. Kearfott Gyro S/N 4 was partially torn-down, witnessed by NASA and Kearfott representatives, and no indication of over-heat was noted on the temperature indicator. Gyro S/N 4 underwent the same Grooming and Testing procedures as Gyro S/N 2 except for system tests in the RMP.

6. Sperry experience has shown that the size of particles sufficient to cause float stiction is minutely small and the probability of finding such a particle when a unit is torn down is very low.

7. A particle in the fluid gap cannot be "created" by overheating the unit; it must be present somewhere in the fluid from the time the unit was initially assembled.

8. The Kearfott Gyros purchased under the referenced P.O. are required to pass vibration tests. Such vibration tests are capable of causing a particle to migrate to a critical fluid gap, resulting in the float stiction actually observed.

9. The presence of such a particle was observed only after vibration and thermal vacuum tests.

D

6/18/68

CN/P #66

Conference held at Sperry Gyroscope on 5/21/68

Attendees:	NASA	G.E.	Sperry
	R. Shelley	R. Birch	R. Domini T. Wood A. Squillante H. Wendel

1. Acceptance Test of RMP S/N 6

Acceptance test of RMP S/N 6 commenced at approximately 1100 hours witnessed by Mr. R. Shelley, RMP T.O. from NASA, and Mr. R. Birch of G.E. The Nimbus D RMP Acceptance Test Procedure, T4310-10360 was strictly followed.

Testing proceeded normally through paragraph 3.6, with all readings within specification. At about 1430, the Hysteresis Test, para. 3.7 was initiated. The baseline RMP output was +5 mv, corresponding to a + 0.17 degree/hour bias. As prescribed by the test procedure, a +5 ma bias current was injected into the torque feedback loop from the BTE for a period of 5 seconds, then removed. During this 5 seconds the gyro float stands off from its null position approximately 10 arc minutes. The RMP did not return to the baseline value, but rather returned to a value of +25 mv (+0.87 deg/hr) and then commenced to ramp smoothly for the next hour to a value in excess of +100 mv (+3.5 deg/hr).

A direct measure of the torquer voltage confirmed this was not an error in readout voltage, but a true mechanical torque on the gyro float.

A small current was summed into the loop from the BTE. The change in output voltage was correct for the inputcurrent indicating the gyro float was not sticking, but rather was being acted upon by some sort of spring. By measuring the torque (bias) change as a function of float angle, the value of this spring was estimated to be 2.6 dyne-cm/arc minute, which is much greater than the normal output axis spring rate.

The torque feedback loop was disabled and it was noted that the gyro float quickly displaced about 2 arc minutes confirming the magnitude of the spring.

Upon restoring the loop, the RMP output returned immediately to the original baseline value of +5 mv. A subsequent negative, then positive hysteresis test resulted in normal output returns, but the next positive test resulted in a return to +150mv (+5.2 deg/hr). The next negative test resulted in a return to +120 mv. Without further testing, the unit was allowed to run overnight, during which period the RMP output slowly drifted from the +120 mv value out to +155 mv, then gradually reversed and drifted back to +110 mv by 0840 the next morning. Two more Hysteresis tests resulted in output readings of +180 mv, and +155 mv respectively. The unit was then commanded off. A sample of the test data is included in Appendix A.

2. Retest of Kearfott Gyro, S/N 2

On 5/27/68 the Kearfott Gyro S/N 2 was removed from RMP S/N 6. Sperry/NASA agreed to conduct hysteresis tests on the unit on the gyro test station. Hysteresis tests were conducted per T Spec #4310-10842. A chronological summary of the tests results is presented.

5/29/68 - The gyro was mounted on Test Stand #20 Output Axis Vertical Positive end Up and IA directed East. When stabilized at the operating temp. of 164°F the wheel was energized with 26 V 3 Ø sine wave excitation. At this time the gyro exhibited a bias of .008°/hr. Wheel excitation was removed and the electronics shut down. The gyro was left at room temperature in this attitude over the weekend.

5/31/68
0800 Heater and electronics on and gyro stabilized at 164°F. Wheel excitation applied. Gyro bias at this time was again .008°/hr. Torque feedback loop opened and float driven to 18 mv out-of-phase for 30 sec. Equivalent to 10 min. per T Spec. 4310-10842. Loop closed and rate stabilized at .008°/hr. Repeated in-phase and for 3 cycles. Each time rate returned to .008°/hr. Excitation removed and electronics shut down. Gyro allowed to cool down to room temperature.

5/31/68
1415 Electronics on and gyro temp. stabilized. Output axis vertical positive end up and IA directed East. Wheel excited. Gyro bias erratic between +6.8 and +5.6°/hr. Open loop - drive to 18 mv., in phase. Close loop - rate returned to +3.2°/hr. Open loop - drive to 18 mv out of phase. Close loop - rate returned to +0.30°/hr. Open loop - drive to in phase stop - 335 mv. Close loop - rate returned to +0.02°/hr. A sample of this test run is included in Appendix B. Excitation removed - electronics off. Gyro allowed to cool to room temperature in this attitude over weekend.

6/4/68
1330
Witness
T. Wood
F. Yake Electronics on - stabilized at 164°/hr. Wheel excited. Gyro Bias was -5.6°/hr. Open loop - drive to in phase stop. Close loop - rate returned to .04°/hr. Hysteresis test repeated for 3 cycles. Each time rate returned to .04°/hr. Data witnessed by Mr. T. Wood (Engr.) and Mr. F. Yake (Q.A.). Wheel & electronics off. Gyro removed from stand.

CNAP #67 8/15/68

Conference Held at Kearfott on 8/6/68

Attendees:	NASA	G.E.	Sperry	Kearfott
	A. Babecki	R. Birch	R. Domini	T. Brophy
	R. Shelley		A. Squillante	F. Schaume
	L. Arnowitz			S. Golding

Subject: Teardown of Kearfott Gyro S/N 2

1. The meeting was held at Kearfott to witness the teardown of Kearfott Gyro S/N 2. Gyro test data obtained at Sperry (CNAP #66) and at Kearfott was reviewed. This data indicated the bias anomaly was witnessed at Sperry and at Kearfott.

The temperature indicator strip located under the gyro cover was reviewed. This indicator has temperature sensitive "dots", calibrated at 180°F - 200°F - 230°F and 250°F, which are normally dull gray and turn black when the specified temperature is reached. The 180°F, 200°F, and the 230°F dots were black, indicating that some time during the life of the gyro, it was subjected to 230°F or 50°F above the maximum storage temperature.

2. The attendees witnessed the step by step teardown of the unit. The following are general comments:

- Visual Inspection of outer package parts and the hermetic sealed float assembly indicated no apparent signs of overheat, ie no bellows, jewel pivot or stop damage. The heater sensor strip was not available for inspection. No obvious signs of hang up, ie wiskers or foreign particles was noted.

- The parts were cleaned to remove all traces of the damping fluid and were re-inspected under a microscope. No obvious signs of permanent damage was noted. The "Delvin Stop" was closely examined and compared with "new stops". No signs of overheat were apparent, however, some fibres were protruding from the surface of the stop. The "hang up" and measured high torcional restraint could be caused by one of these fibres breaking loose and contacting the float in a close clearance area.

3. Problem and Action Items

As a result of the teardown the following items were listed and action items agreed to:

Problem

3.1 Excessive settling time of gyro - witnessed at Sperry.

3.2 Intermittent stiction (hang-up) during final hysteresis test at Sperry.

3.3 Intermittent stiction (hang up) during unit re-test both at Sperry and Kearfott.

3.4 Intermittent stiction during yozzle test at Kearfott upon return of unit.

3.5 Evidence of unit being subjected to 230°F - 250°F - Noted at Kearfott.

Action Items

3.6 Kearfott to continue detail mechanical inspection of parts.

3.7 Re-assemble critical parts to try to duplicate problem (Kearfott)

3.8 Inspect temperature sticker on Prototype IMP S/N 5, Kearfott Gyro S/N 1 (NASA/GSFC)

3.9 Kearfott to review Reliability data for similar type malfunctions.

3.10 Elevate temperature sticker from Gyro S/N 2 to 250°F to check calibration of last lot (NASA/GSFC).

3.11 Sperry - Review procedures for assembly and test of Kearfott Gyro for over temperature possibilities.

3.12 Sperry, Kearfott, NASA/GSFC - check temperature sticker on Kearfott Gyro S/N 4 at Sperry. Unit has completed FAT test.

3.13 Include hysteresis tests as trend data on ATS at GE. (NASA/GSFC).

3.14 Test temperature sticker design - calibration in vacuum etc. (NASA/GSFC).

4. Open Items

4.1 Failure Analysis & Corrective Action. Problem of overheat and contamination may be separate. Must review all assembly procedures to insure proper screening of units. Must obtain confidence in remaining three Kearfott gyros, in that contamination is not a problem with all units.

4.2 Disposition of Kearfott Gyro S/N 2 - Rebuild ?

4.3 Disposition of RMP S/N 6 - RMP S/N 6 will be held at Sperry until teardown analysis completed on Kearfott Gyro S/N 2.

GENERAL PRECISION SYSTEMS INC.
KEARFOTT GROUP

1150 McBRIDE AVENUE, LITTLE FALLS, N. J. 07424 | 201-256-4000 | TWX 710-988-5700
KEARFOTT SYSTEMS DIVISION

Reference: 68-4305

August 23, 1968

Sperry Gyroscope Co.
Great Neck, Long Island
New York 11020

Attention: Mr. R.F. Thomson
Buyer

Subject : Failure Analysis Report for Gyro C702564015-1
Serial No. 2, dated 16 August 1968

Reference: P.O. C317110-82

Gentlemen:

Transmitted herewith is one (1) copy of the subject document.

Very truly yours,

KEARFOTT SYSTEMS DIVISION

E.C. Sental, Sr.
Sr. Contract Administrator

ECS:ml

Enclosure

Kearfott Systems Division

Failure Analysis Report

C70 2564 015-1

Floated Rate Integrating Gyro

Serial No. 2

August 16, 1968

Prepared By: ______________________
L. Wells
Quality Engineer

Approved By: ______________________
M. J. D'[illegible]
Section Head, Quality Engineering

I History

C70 2564015 gyro, S/N 2, was assembled for Sperry Gyroscope Company for the Nimbus program, tested in accordance with Acceptance Test Procedure C182564015 Revision A without incident, and delivered to Sperry on 11/20/67. The unit was received by Sperry, subjected to incoming inspection and test, accepted, and assembled into RMP S/N 6. During the acceptance test of the package at Sperry on or about 5/21/68, the gyro float was torqued off null with a bias current of +5 ma in accordance with the test procedure. When the bias current was removed, the gyro float failed to return to its original position. Further diagnostic tests confirmed the existence of a torque causing the float to displace. The gyro was removed from the package, mounted in a G insensitive attitude and periodically tested between 5/29/68 and 6/4/68. These tests confirmed an erratic gyro bias. The unit was rejected and returned to KSD on 6/11/68 for verification and analysis.

II Verification Findings

The following verification program was conducted:

A. Visual examination - on 6/18/68, the unit was examined and no significant defects were noted, except what appeared to be thermal vacuum grease on outer case.

B. Resistance checks - on 6/25/68, resistance and insulation resistance was checked and found to be within specification.

C. Six position drift test - on 6/26/68, a six position drift test was performed. All parameters were within specification; however there was a change in fixed torque (R_o) from the pre-ship F.A.T. data. (See tabulated data)

D. Stiction test - on 6/27/68 and 6/28/68, motor off stiction tests were performed with positive and negative slews with the gyro oriented OA up and down. Definite stiction hang-up occurred at several points in the test.

E. Yozzle test - on 7/1/68, yozzle tests were conducted, and did exhibit an unusual discontinuity coming off the in-phase stop.

F. Six position tests - on 7/5/68 and 7/8/68, two six position tests were conducted and the values obtained during the test of 6/26 were approximately duplicated. (See tabulated data)

G. Degaussing - the gyro was degaussed on 7/8/68.

H. Six position test - on 7/8/68 a six position test was performed after degaussing, and a significant change in R_o was noted (see tabulated data)

Parameter	Spec	FAT A 11/6/67	FAT B 11/7/67	FAT C 11/8/67	Verif 6/26/68	Verif 7/5/68	Verif 7/8/68	After Degaussing Verif 7/8/68
Torquer Scale Factor	134±13	136.1	135.8	136.1	135.1	135.8	135.6	135.8
R_o	±2.0	-.011	-.020	-.024	-.463	-.353	-.360	+.020
$\overline{\text{MUSA}}$	+1.0	+.338	+.303	+.259	+.816	+.732	+.715	+.611
MÛIA	±1.0	+.105	+.098	+.095	+.074	+.014	+.196	+.217

To further evaluate the failure, disassembly of the unit was directed. Key personnel from Sperry, G.E., NASA and KSD were scheduled to witness the teardown. In preparation for the teardown, external covers and wiring were removed. During this preliminary teardown, it was noted that the temperature indicating device, installed during initial assembly, indicated that the gyro had been overheated to a temperature in excess of 230°F but less than 250°F. On 8/6/68, the teardown was performed and witnessed by the following people.

Mr. L. Aronowitz	NASA
Mr. R. Shelley	NASA
Mr. A. Barbeki	NASA
Mr. A. Squilanti	Sperry
Mr. R. Domini	Sperry
Mr. R. Birch	G.E.
Mr. T. Brophy	KSD
Mr. P. Schauer	KSD
Mr. L. Wells	KSD

Teardown of the unit failed to reveal any significant defects, and although some minor imperfections were questioned, it was agreed that the unit was clean and free of discoloration, damage, or faulty workmanship.

To complete the analysis, mechanical measurements were made of the disassembled parts to determine that internal gaps between adjacent parts were sufficient to prevent interference and hang-up. The following tabulated data shows the results of those measurements.

Parameter	Design Requirement	Measured Value	Remarks
Float OD Size (2 places)	$1.5070^{+.0000}_{-.0010}$	1.5073 1.5063	.0003 OHL
Runout of Float OD from jewel (2 places)	.0005TIR	.0004 .0003	
Torq Rotor OD Size	1.218 Max.	1.214	
Torq Rotor ID Size	1.134 Min.	1.1316	.0024 ULL
Runout Rotor OD	.0005 TIR	.0005 TIR	
Runout Rotor ID	.0005 TIR	.0025 TIR	Irregular .0020 OHL
End Bell Hsg ID Size	$1.230^{+.002}_{-.000}$	1.2320	
Runout EB Hsg ID from M.S.	.0005	.0004	
Return Path OD Size	$1.120^{+.000}_{-.002}$	1.1188	
Runout Return Path from M.S.	.0015 TIR	.0001	
Gyro Hsg. ID Size	1.527±.001	1.526	
Runout Hsg ID to Pivot OD	.002 TIR	.0010	
Float End Play	.0010 to .0015	.00105	

In addition, pivot and jewel diameters were measured for roundness and surface irregularities. Profiles obtained were indicative of acceptable parts. See Fig. I.

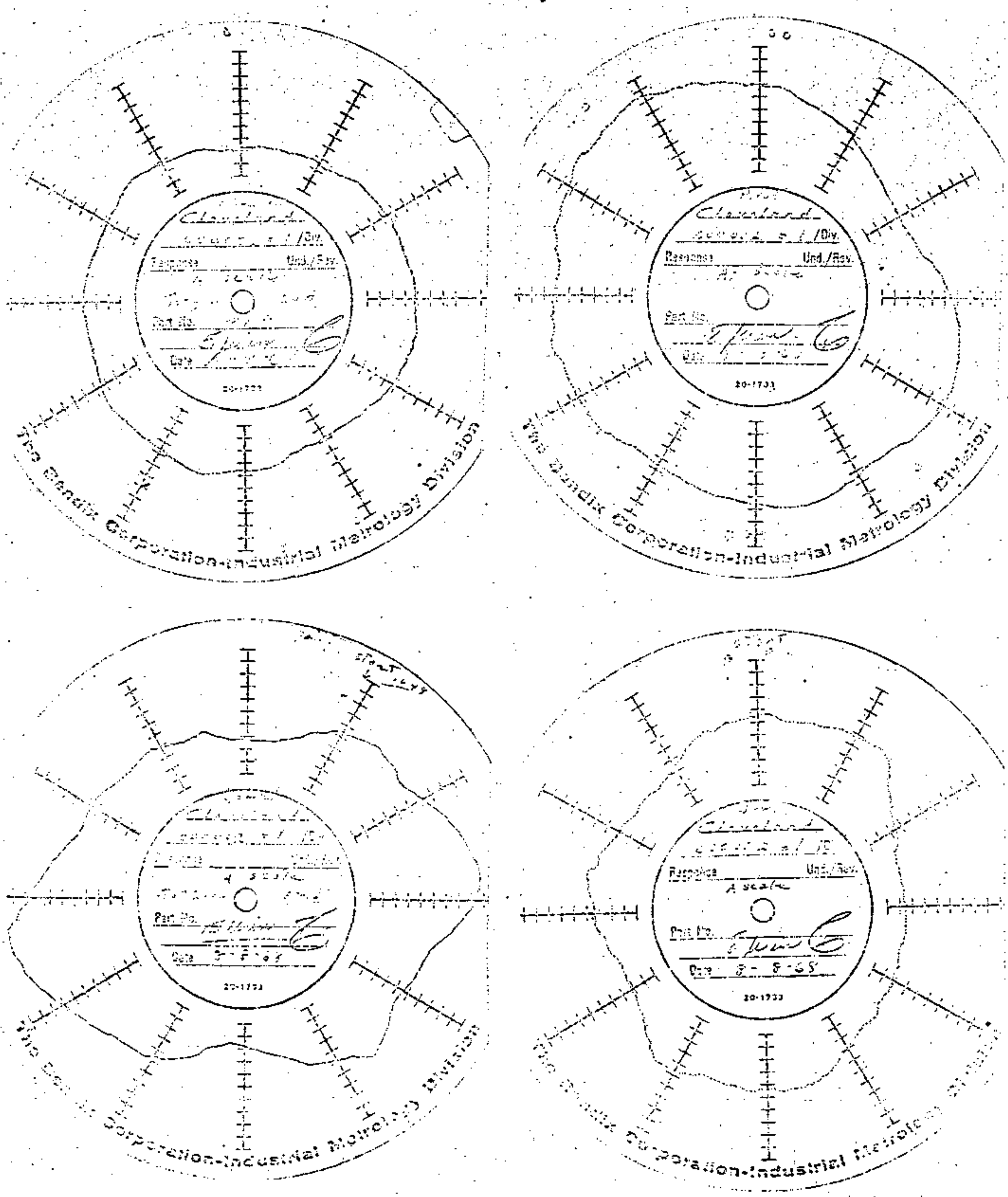
III **Conclusions**

The nature of the failure appears to be stiction. Test results and teardown findings indicate that stiction was intermittent and probably caused by a particle in the fluid migrating to a critical gap; most likely between the pivot and jewel. The change in the restraint level was magnetic in nature since degauss resulted in the original restraint value being obtained. The gyro appears to have been exposed to a high temperature environment, and a magnetic field. Since no evidence of internal contamination was visible during teardown and no other significant defects were noted, the exact cause of failure cannot be stated; however, in the absence of such evidence, we must rely on experience and judgment to determine the probable cause of the failure. Based on the evidence at hand, it is KSD's judgment that the overheating of the gyro developed a condition which caused the reported failures. Since the gyro was heated above its operating temperature, the internal pressure would have reached critical levels sufficient to cause this failure.

IV **Corrective Action**

The failure is attributed to exposure to abnormal environments at the customer's facilities, and no corrective action is anticipated at KSD. However, it is recommended that Sperry investigate the use of this unit in an effort to uncover the source of high temperature and magnetic field.

FIGURE I


Cleveland
Response
Und./Rev.
Part No.
Date
20-1733
The Bendix Corporation-Industrial Metrology Division

Appendix VI

SYSTEM ENGINEERING PROGRAM PLAN FOR NIMBUS D RMP CONNECTOR CHANGE

System Engineering

Program Plan For

Nimbus D RMP Connector Change

Contract NAS 5-10391

A.O. 33506

J.E. 7004-0

W. Kozma 3/11/69

Prepared by: T. Wood 3/10/69
T. Wood/W. Kozma

Approved by: R. Domini 3/14/69
R. Domini,
Engineering Manager

Date: March 1969

6

1. INTRODUCTION:

1.1 This Program Plan describes the tasks associated with change of the Nimbus D RMP Connectors from gold over gold to gold over silver plating as directed in Contract Modification #9 to Nimbus D RMP, Program NAS 5-10391, dated 12/20/69.

1.2 It should be noted that based on past experience at Sperry Gyroscope Division, use of gold over silver connectors has resulted in serious problems such as intermittent contact due to generation of silver sulfide which emenates thru the sometimes porous gold over-plating.

The direction to use gold over silver plated connectors on the Flight RMP and Space RMP as specified in Contract Modification #9 will be followed. It is necessary, however, to inform NASA/GSFC of Sperry's experience with gold over silver-plated connectors. This information had been presented at several meetings at GSFC during August and October 1968 and recorded in various telecons and Nimbus Program CNAP's. A NASA/GSFC Parts and Components Evaluation Report PACER 201-001 issued March 30, 1965 substantiates Sperry's findings with respect to formation of silver sulfide. A copy of the appropriate section of this report is included in the addendum.

In conclusion, Sperry advises against the use of gold-silver finish on contact surfaces; however, Sperry will follow the direction of Contract Modification #9.

1.3 The Program Plan consists of the following major tasks:

Task 1 - Rework of RMP S/N 7
Task 2 - Rework of Kearfott Gyro Connectors
Task 3 - Rework and Requalification of RMP S/N 6
Task 4 - Fabricate Spare Harness, RFI & Inverter
Task 5 - Program Management

2. SCHEDULE:

2.1 Figure 1 illustrates the schedule requirements for the 5 tasks of this program.

3. TASK/MILESTONE DESCRIPTION:

The following paragraphs describe the tasks and milestones per the tasks listed on the schedule (Figure 1).

Task 1 - Rework of RMP S/N 7

This task covers the work associated with modifying the existing harness & RFI (P/N 4216-90956-2 and P/N 4310-90627-902) S/N 7 and Inverter Subassembly (P/N4310-90433) S/N 7 from the mainstream Nimbus D RMP program to:

1) eliminate solder voids in the connector cups
2) change connectors from gold over gold to gold over silver
3) add rigid heat shrinkable tubing where possible on the existing harness.

To accomplish the first objectives of this task a sound technical approach has to be taken to develop a procedure for obtaining satisfactory (void free) solder joints. Once this procedure has been developed, re-soldering of the harness and inverter with gold over silver connectors can be initiated.

Sub-task 1.1 Develop Soldering Technique and X-Ray Procedure

Sample solder connections will be made using Cannon and Continental (gold over silver plated) connectors. X-rays will be taken to examine the solder joints to determine which are acceptable. These x-rays and the solder technique will be reviewed by NASA/GSFC personnel.

The approach to be taken is as follows:

- Consult with both Sperry Materials Department and NASA/GSFC Materials Department for soldering information.

- Investigate connector soldering by other companies such as SPACO, Kearfott, etc.

- Contact connector manufacturers & soldering iron manufacturers for soldering information.

Perform controlled tests to isolate the cause of voided solder connections, and obtain acceptable solder joints. Investigate the effects of the following proposed variables:

Heat application

- duration
- area
- control

Iron type
Solder type
Flux type & pre-fluxing of leads & cups
Pre-tinning of leads & cups
Wicking methods
Soldering sequences
Cleaning procedures

- including mechanical & chemical cleaning
- plating effects & connector size effects

Further testing will be necessary to develop a procedure for retouching voided connections. In addition, connector acceptance criterion must also be established.

It is expected that the testing will necessitate approximately 50 tests utilizing thirty connectors. Assuming that one to two connectors will be soldered per day, and alloting time to x-ray and evaluate, the testing should take about 3 1/2 months (including 2 1/4 months for soldering).

Note: All soldering tests will be witnessed by engineering or Sperry Q.A.

An Engineering Bulletin detailing the soldering technique and x-ray procedure will be generated and included on the appropriate drawings. Drawings will be modified to reflect the new E.I., plus an informal engineering report will be written summarizing results.

Sub-task 1.2 - Connector Change

Harness S/N 7 and Inverter Assembly S/N 7 will first be x-rayed to determine the extent of solder voids in connector cups. This will be accomplished at NASA/GSFC, with Sperry Engineering and Q.A. in attendance.

All connections will be marked and labeled to facilitate re-connection and eliminate wiring termination errors. The Cannon connectors will be removed and GFE gold over silver Cannon connectors with thick wall heat shrinkable tubing (GFE) will be reconnected. All connector rows shall be x-rayed and specific pins will be re-touched as required to obtain acceptable connectiosn. After acceptable x-rays have been obtained (approval of NASA/GSFC) and the connections have passed NASA/Sperry visual inspection the heat shrinkable tubing will be placed over the connections and shrunk in place.

The same procedure will be followed with the Continental connectors, with the exception that gold over gold plating will still be used on Harness S/N 7 and Inverter S/N 7 to minimize schedule delay. These connectors will be taken out of Nimbus D stock. In addition thin wall heat shrinkable tubing (Kynar) will be employed on these connectors.

No modifications will be made to the solder connections on the Elco connectors as these are straight pin types.

After completing the re-work of the harness and inverter, termination checkout and C & R test will be repeated and appropriately noted. The harness will then be available for assembly into RMP S/N 7. The schedule (Figure 1) notes the availability date of the reworked harness.

Task 2 - Rework Kearfott Gyro Connectors & Normalization Package

This task includes all the necessary effort to rework the gyro connectors and gyro normalization packages. Three Kearfott gyros and normalization packages will be reworked, S/N 2, S/N 3, and S/N 4. The work effort will be broken down as follows:

. Kearfott Gyro S/N 4 - Rework for RMP S/N 7. Use gold over gold connectors (schedule purposes) identify each wire and re-solder using new technique. X-ray connector solder joints and submit x-rays to NASA/GSFC for approval. Use Kynar thin wall shrinkable tubing. Perform minimal re-FAT of gyro.

. Normalization Package S/N 4 - Rework for RMP S/N 7. Use gold over gold connectors, rewire entire package, re-solder x-ray and re-inspect. Submit x-rays to NASA/GSFC for approval.

. Kearfott Gyro S/N 3 and S/N 2 - Order new gold over silver Continental connectors, re-solder, x-ray and inspect. Use Kynar thin wall shrinkable tubing. Perform re-FAT of each gyro.

. Normalization Packages S/N 3 and S/N 2. Order new gold over silver Continental connectors, remove conformal coating rewire both packages, x-ray and re-inspect. Submit x-rays to NASA/GSFC for approval.

Task 3 - Rework and Requalification of RMP S/N 6

RMP S/N 6 had been fully qualified ready for acceptance and placed on hold until resolution of the soldering/connector plating problem. This task covers the work scope associated with disassembly of RMP S/N 6, reassembly with spare parts and full FAT and qualification testing. In summary the work effort will include:

. Removal of Kearfott Gyro S/N 3 and x-ray of the gyro and normalization connectors. Witness of this task and examination of the x-ray by Government Representative at Sperry.

. Removal of PC cards, Inverter, Harness and RFI assembly. All items are to be placed on hold.

. The mechanical-structure must be cleaned and placed in Flight Hardware condition. RMP S/N 6 shall be re-assembled with the spare PC cards, Harness and Inverter, all S/N 6A and reworked Kearfott Gyro S/N 3.

Perform FAT and Flight Level TV Qualification Testing of RMP S/N 6 at Sperry per appropriate Sperry test specs. Perform Flight Level Vibration at GSFC. See schedule in Fig. 1 for milestone. Delivery of RMP S/N 6 is scheduled for 15 June, 1969.

Task 4 - Fabricate Spare Harness, RFI & Inverter Sub-Assembly

This task covers the work associated with manufacture of a new Harness & RFI assembly P/N 4216-90956-2 and 4310-90627-902, Inverter Subassembly P/N 4310-90633. Specific items are:

. Order Detail electronic components for the RFI and Inverter plus sheet metal parts. Purchase Hi Rel items where applicable and screen standard parts per the Sperry Screening Procedures.

. Order Space Wire as required and new short pin, gold over silver, Elco connectors, and gold over silver Continental connectors.

. Use GFE gold over silver Cannon connectors.

. Make all necessary drawing changes per latest connector information and fabrication information for harness. Generate E.B. for harness fabrication.

. Fabricate one Harness and RFI Assembly and Inverter Subassembly, x-ray wll connections (excluding Elco's) and inspect. X-rays must be reviewed and accepted by NASA/GSFC.

Task 5 - Program Management

Provide Program Management consistent with level of effort of this add-on-program.

. Overall responsibility of this task in conjunction with the Nimbus D main stream program.

. Customer liaison

.Coordinate all Sperry efforts including contributing departments, i.e., Q.A., Design, Purchasing, and Works Management.

. Cost and schedule control information, generation of task plan and necessary estimates and control of budgets.

. All task documentation including plans and progress reports, telecons, conference notes and submission of engineering data as required.

ADDENDUM

MAY 6 Rec'd 9440

PARTS AND COMPONENTS EVALUATION REPORT

PACER 201-001

REVIEW OF THE PROBLEM OF THE FORMATION OF INSULATING FILMS ON GOLD PLATED CONTACT SURFACES

MARCH 30, 1965

FAILURE ANALYSIS SECTION
QUALITY ASSURANCE BRANCH
GODDARD SPACE FLIGHT CENTER

OPTIONAL FORM NO. 10
5010-104

UNITED STATES GOVERNMENT

Memorandum

PACER 201-001

TO : Distribution List

DATE: March 30, 1965

FROM : Mr. J. C. Rubin
Test and Evaluation Division, OTS

SUBJECT: Review of the Problem of the Formation of Insulating Films on Gold Plated Contact Surfaces

SUMMARY

Contact surfaces of electrical connectors, electroplated with gold in accordance with MIL-G-45204 specification, have been reported to develop semiconducting or insulating films in the presence of sulfur-bearing atmospheres. The condition is especially critical for circuits operating at low voltage and low current levels. Investigations have shown that the base metals of the contacts, such as copper, zinc, and silver, beneath the gold plating, combine chemically with atmospheric sulfur, producing a sulfide which diffuses through the gold to form films on the contact surface. Attempts to minimize the problem have led to only two promising solutions:

(a) gold over nickel plating.
(b) hard gold over soft dense gold plating.

A survey of handling techniques for gold plated connector contacts indicates that alumina-in-alcohol cleaning can remove considerable amounts of the film buildup without damaging the gold plating, and that use of silver-saturated protective cloths, shrouds or filters tends to retard film formation in sulfur-bearing atmospheric environments.

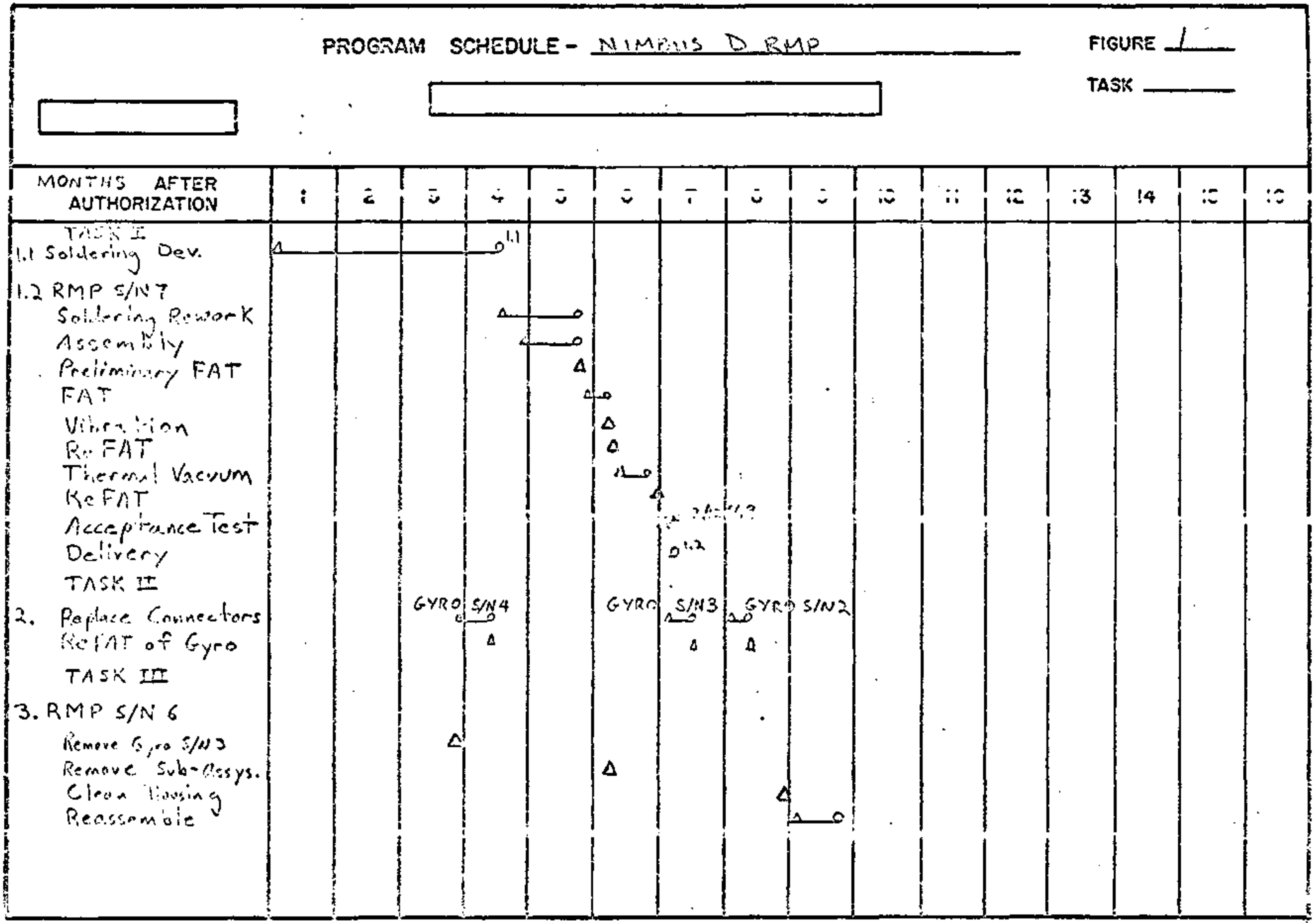
INTRODUCTION

Although not widely known among component or design engineers, it has been well established in electroplating literature that thin gold plating over copper or silver is insufficient to prevent formation of discoloring surface films after months of storage, even in "clean" atmospheric conditions; in the case of marine or industrial atmospheres the film formation period can be reduced to weeks, or in extreme cases, even to days. This visible evidence of film formation on contacts has not been publicized outside the electroplaters' technical literature, nor has a solution to the problem been proposed, inasmuch as field performance of discolored connector contacts has not, until recently, been recognized as a problem.

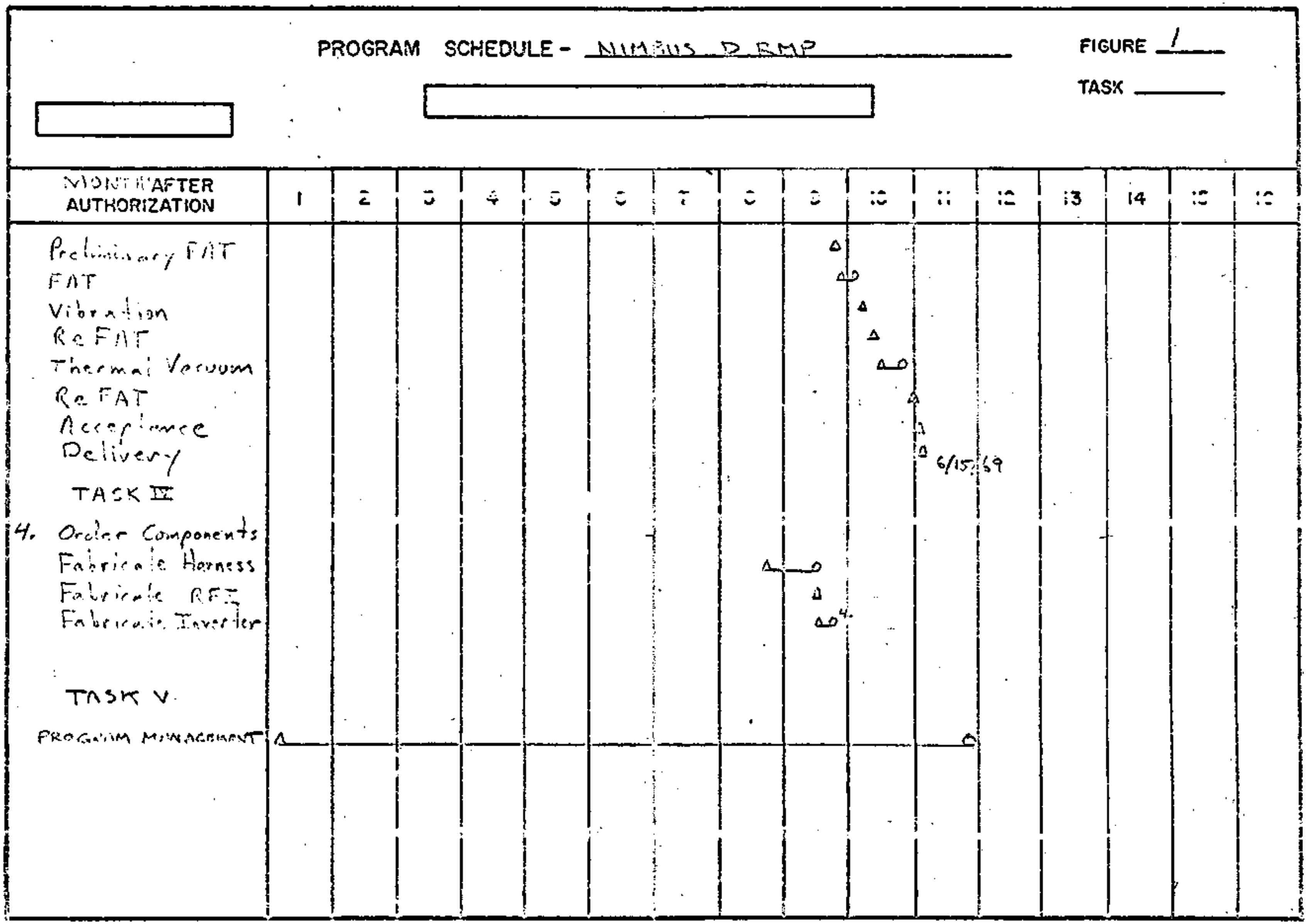
Routine handling of connectors in assembly, and repeated mating and unmating of connectors has generally proven sufficient to initially scrape away any surface film. After assembly, the film has not presented a problem because circuit applications have usually involved voltage and current levels of sufficient magnitude to maintain normal contact operation by breaking through the film as it formed. Film formation can however become a problem of serious magnitude if voltage and current levels are too low to rupture the films. Under these conditions, high-impedance operation, rectification, intermittent contact, or complete open circuit operation can take place, dependent on the severity of film formation and the signal level.

The primary objective of this report is to bring the past history and present knowledge of the diffusion-migration and film formation problem in gold plated connector contacts to the attention of interested NASA personnel, and to examine, on the basis of the latest available information, the effectiveness of the most popular and the most promising approaches to reduction and correction of this problem. While much of the study has been confined to the nonmagnetic type of contact (free of iron and nickel) the information and conclusions are generally applicable to all connector contacts and to many gold plated electrical surfaces.

INERTIAL COMPONENTS
DEPT. 4217



INERTIAL COMPONENTS
DEPT. 4217



Appendix VII

REPORT ON MALFUNCTION OF RATE MEASURING PACKAGE FT04

GSFC MALFUNCTION REPORT

NO. A-00806

(1) Project: NIMBUS "D" RMP
(2) Spacecraft:
(3) Operation: 1048
(4) Units: 1 [x] Hrs 2 [ ] Cys

(5) System or Experiment: VIBRATION QUAL TEST
(6) Date & Time of Malfunction: Yr 69 Mo 1 Day 23 Time 1430
(7) Date of Report: Mo 1 Day 27
(8) Critical: 1 [ ] Yes 2 [ ] No

	NAME	IDENTIFICATION NUMBER	SERIAL NUMBER	MANUFACTURER
(9) Component	RMP	4310906-41	7	SPERRY
(10) Assembly				
(11) Sub-Assembly	HARNESS ASSY	4216909562	7	SPACO
(12) Part	WIRE	Manufacturers Part Number: 1404-11269	Circuit Des. 262	RAYCHEM

(13) Malfunction Occurred During: 1 [x] Qualification Test 2 [ ] Acceptance Test 3 [ ] Integration Test 4 [ ] Pre Launch 5 [ ] Launch Operations 6 [ ] System Test 7 [ ] Bench Test 8 [ ] Post Launch

(14) Environment When Failed: 1 [ ] Acceleration 2 [ ] Shock 3 [ ] Thermal-Vacuum 4 [ ] Temperature 5 [ ] Humidity 6 [x] Vibration 7 [ ] Ambient 8 [ ] Acoustic

(15) Action to be Taken on Failed Unit: LEAD TO BE SPLICED AND RESOLDERED
Document Number that Authorized Failure Analysis:

(16) REFERENCE
RMP Log Book # 1 Page 23 Test Procedure 4310-10680 Para 8

(17) Description of the Malfunction: FAILURE NOTED AT POST VIBRATION F.A.T.
LOSS OF 12V TEST POINT. NO FUNTIONAL EFFECT ON RMP.
PROCEDURES WILL BE CHANGED TO PROVIDE CORRECTIVE ACTION.
THE HARNESS WILL BE LACED TO ADJACENT UNUSED TERMINALS
AND WILL BE CONFORMAL COATED UNDER THE RFI PACKAGE.

(18) Originator: A. Toole Phone: 516-574-1446 Organization: Sperry Gyro Div., Sperry Rand

Do Not Write Below This Line

INSTRUCTIONS

(1) Originator -- Fill in blocks (1) through (18), with all known information, as defined in instructions on the back of this form.

(2) Distribute copies in accordance with project directions.

GSFC 4-2(8/67)

Copy 1

SPERRY

MATERIAL REVIEW REPORT NO. 28420

DISTRIBUTION:

GOVT — ENGRG — OTHERS — MRB

VENDOR FILE — BUYER — INSP/TEST — VENDOR

PART NO. OR MATL-2	REV	PART NAME	A.O.	PROD NO.	CONTRACT NO.
9216-90956	D	HARNESS ASSY	33506	302	NAS5-10391

QTY RECD	QTY WITHLD	Q.C. DEPT NO.	R.R. OR P.O. NO.	MOD	VENDOR
1	1	4670	C323069-8		SPACO INC.

REASON FOR WITHHOLDING	○	DISPOSITION
WIRE BROKEN ADJACENT		REPAIR - SPLICE
TO TERMINAL J7-23		PER INSTRUCTIONS
DURING ENVIRONMENTAL		OF T. WOOD - ENG.
VIBRATION TEST.	C	
NOTE: THIS ASSY IS NOW		SOLDERED BUTT
PART OF RMP ASSY		CONNECTOR WITH
9310-90641 SERIAL NO. 7		DOUBLE WALL SHRINK
		TUBING.

REFERENCE DOCUMENT(S)

RESUBMIT TO MRB

FREQUENCY SYMBOLS A-FREQUENT B-SELDOM C-FIRST TIME

RESUBMIT ACCEPTANCE Q.A. F. Valee DATE 1-28-69

WITHHELD BY			MATERIAL REVIEW BOARD	
INSPECTOR/TESTER	SUPV	DATE	QUAL. ASSURANCE F. Valee	DATE 1-27-69
			ENGRG R.H. Wood	DATE 1-27-69
REPAIR AUTHORIZATION ... APPROVAL	Dana Hirsch	DATE 1/28/69	GOVT R. Shelley	DATE 2/24/69

PART NO. 9216-90956-2

CORRECTIVE ACTION

ASSY PROCEDURES WILL BE CHANGED.
THE HARNESS WILL BE LACED TO ADJACENT
UNUSED TERMINALS AND WILL BE CONFORMAL
COATED UNDER THE R.F.I. PACKAGE.

PARTS DISTRIBUTION	QTY
ACCEPT	
REJECT	
REWORK	
REPAIR	
RETURN TO VENDOR	

EFFECTIVE DATE 1-27-69 SIGNED F. Valee DATE 1-27-69

F

CNAP #80

Conference held at NASA/GSFC on 2/3/69

Attendees:	NASA	SPERRY
	R. Shelley	R. Domini
	S. Weiland	T. Wood
	H. Press	
	R. Devlin	

Subject: Flight Model Nimbus D RMP S/N 7

1. The purpose of the meeting was to review in detail the repair of the broken lead in RMP S/N 7.

2. Post vibration FAT testing on 1/24/69 indicated an open in the BTE/RMP test circuit in RMP S/N 7. It was determined that a broken lead occurred at Pin #J7-23 on the Elco Connector. At that time it was agreed upon by NASA/Sperry to open RMP S/N 7, lift the RFI assembly and splice a new wire in place. The repair was made and RMP S/N 7 was placed in TV test.

3. RMP S/N 6 system was used to demonstrate how the repair was accomplished on RMP S/N 7. A brief description of the repair was given. After securing the RFI assembly in a raised position, two sections of lacing were removed from the wire bundle to free the broken wire end. The lead was redressed, tinned, and inserted into one end of a tinned splice sleeve. The end of the wire was hooked through an opening in the sleeve. The same procedure was used to secure a length of wire to the other end of the splice sleeve. The splice sleeve was then filled with solder and a double walled polyolefin sleeve shrunk over the splice. The wire was reconnected to terminal J7-23. The splice and wire bundle were securely laced together and to the adjacent unused terminals on J8 for added support. Before securing the RFI assembly in place, all harness bundles were conformally coated.

4. It was mutually agreed upon by all attendees that a workmanship vibration would not be performed on RMP S/N 7 as a subsystem. It was the opinion that the repair was sound and that no adverse effect was imposed on other wires and harness bundles as a result of making the repair. In addition, the system would be vibrated as part of the ACS and again when integrated with the Nimbus D S/C.

5. Per Sperry's recommendations regarding modification of all existing BTE consoles (see CNAP #72, with attached Nimbus Telecon #542/...

This trip provided the opportunity to modify BTE S/N 1 at GSFC according to the procedure detailed in the appendix of telecons #542/543. The control panel of the S/N 1 BTE was removed to provide access to the wiring. Inspection revealed that modification a and c were unnecessary as the console was already so wired. Modification b was accomplished by a NASA technician. To accomplish the move of the Current Monitor switch connection from J9 to J12, it was necessary, and desireable, to move the TM return wire from J12 to J9.

BTE's S/N 2 at Sperry, and S/N 3 at GE/VFSTC, have not, as yet, been modified.

Appendix VIII

ELECTRICAL STRESS ANALYSIS AND INHERENT FAILURE RATE PREDICTION FOR NIMBUS D RATE MEASURING PACKAGE

ELECTRICAL STRESS ANALYSIS AND

INHERENT FAILURE RATE PREDICTION

FOR

NIMBUS "D" RATE MEASURING PACKAGE

P/N 4310-90641

(EXCLUDING THE GYRO)

CONTRACT NO. NAS 5-10391

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

Prepared by

Reliability Engineering, Dept. 8220
SPERRY GYROSCOPE DIVISION
Sperry Rand Corporation
Great Neck, New York

Report No. SS-8220-0112
(Supersedes 6220.5128, 3/17/67)

August 1967

1. Introduction

This report presents the final data and conclusions drawn from an electrical stress analysis and an inherent failure rate analysis on the Nimbus "D" Rate Measuring Package less the gyroscope. It presents this information within the context of the conditions given below.

This final edition (August 1967) of the subject report supersedes the preliminary edition (Report No. 6220.5128) dated March 17, 1967, in its entirety. The preliminary report considered the electronics less the SYG-4200 gyroscope. This electrical stress analysis considers the electronics for both the SYG-4200 gyroscope, P/N 4310-90609-901, and the Kearfott gyroscope C-70-2564-015. As a result of incorporation of the Kearfott gyroscope in the Rate Measuring Package, the following changes were required to the electronics:

- Redesign of the Heater Controller PC Card P/N 4216-67678 - Revised to revision letter F.
- Change in RMP control logic. Changes reflected in Relay Card A and Relay Card B, P/N 4310-90848 and P/N 4310-90841 respectively.

The heater controller design, as reflected by the latest revision letter (F), will now operate both the SYG-4200 and Kearfott gyroscopes.

Relay Cards A and B, P/N 4216-67680 and 4216-67681 respectively, will be used with the SYG-4200 gyroscope (new design RMP P/N 4310-90641-901), whereas Relay Cards A and B, P/N 4310-90848 and 4310-90841 respectively, will be required for operation of the Kearfott gyroscope (new design RMP P/N 4310-90641-903).

As a result of the changes indicated, the mean-time-between-failures (MTBF) for the NIMBUS D RMP (less gyro) is as follows:

	Original Design RMP (SYG-4200 Gyro)	New Design RMP P/N 4310-90641-901 (SYG-4200 Gyro)	New Design RMP P/N 4310-90641-903 (Kearfott Gyro)
Failures/10^6 Hrs.	47.1747	47.2528	46.7168
Failures %/10^3 Hrs.	4.7174	4.7252	4.6716
MTBF (Hrs.)	21,197	21,163	21,406

2. Scope and Magnitude of Effort

The stress and failure rate analysis performed on this program was geared to obtaining useful but somewhat limited data at a predetermined level of effort. Working within this concept, the following assumptions and interpretations were made:

- The ambient operating temperature experienced by the parts was 45°C.

- The individual part stress was made under worst case conditions, even though in some instances no real condition existed whereby all parts could simultaneously experience their maximum stress. In those parts in which the worst case condition was of a known short duration, additional consideration was shown by noting the fact on the work sheets.

- The percent of rated stress of the parts was determined by comparing the actual maximum operating stress to the nominal stress level indicated on the part specification drawing. The particular parameters evaluated for the different types of parts are indicated on the work sheets. Where other parameters were also important, they were entered on the work sheets on the appropriate lines. For those components, such as inductors and transformers, where the evaluation during the reliability stress analysis cannot be described in the simple terms of percent stress, the parts were evaluated in terms of the specified operating conditions (inputs and loading).

- The failure rates associated with the parts, evaluated on a worst case basis, will give a total result which is pessimistic by an unknown percentage.

- For purposes of our reliability analysis, all parts were considered to be in use under worst case stress conditions and vital to the overall operation of the RMP. This simplification allowed the arithmetic summation of part failure rates to reflect the total RMP failure rate. A refinement of the analysis would have considered making use of the NIMBUS D RMP system operational profile.

- MIL-HDBK-217A was used to provide the stressed failure rates. The rates given are the "inherent" part failure rates, the source of which is given next to each part designation. The actual failure rates would be larger by an amount which would depend upon the actual environmental conditions the RMP would experience for the periods during which it was functioning.

- A dormant failure rate analysis was not considered to be part of the task assignment.

3. <u>Stress Analysis</u>

In Table 1, the worst case stress data of all parts used in the NIMBUS D RMP are shown in condensed form, taken directly from the reliability analysis work sheets, in major subassembly groupings. The use of the figure of 10% represents a stress ratio at, or less than, 10%. All other figures are the actual calculations. Where "OK" appears in a column, this means that the part is being used within its acceptable limits. This entry is used only where the percent stress of a parameter was not entered on the work sheets. The question marks next to the relays used on Relay Card A and Relay Card B reflect doubt about their particular use, even though it is understood that Goddard requirements forced their operation in this manner. A consideration of other possible problem areas, as indicated by the asterisks, is made later in this section of the report.

Table 2 is a summary, by class and total, of component stress levels. It shows, in stress groupings of 10%, the percentage of components operating within that particular stress level. It is presented for a better insight into the overall component stress structure. The numbers in parentheses following the percentage figures are the actual number of components in that grouping. Again, this is a worst case analysis.

An examination of the stress percentage table, or of the summary of component stress levels, shows that four areas exist where a reliability problem could occur. These are:

- Q402, micrologic amplifier on the T/M Signal Conditioning Card
- C406 on the T/M Signal Conditioning Card
- R3, R4, R5 on the Inverter Subassembly
- K2, K5, K7 on the Relay Card A, plus K1, K4, K6, K8 on the Relay Card B.

Micrologic amplifier Q402 on the T/M Signal Conditioning Card stands out on the stress tables mainly because the rest of the transistors are so conservatively used. The percent of rated power dissipation, which appeared to be about 54%, is only slightly above the usual derating limit of 50% normally put on power rated devices. Since the reliability figure was a calculation of estimating power consumption rather than actual dissipation, the stress percentage could vary either way. It was noted, however, that pains were taken with this component to provide a special heat sink which would remove some of the generated heat and thereby reduce the magnitude of the problem. A close check on the performance of this part in operation would seem to be in order, however. An actual direct measurement of the case temperature during simulated operation would reveal the efficiency of the heat sink and provide additional information on the stress to which the part is subjected.

Capacitor C406 on the T/M Signal Conditioning Card, while normally experiencing only 6.3 volts across it, could, if potentiometer R409 was turned to one extreme, feel the full voltage on line motor Ø C across it. Calculations based on information provided in this area reveal that a voltage in the order of 11 volts peak could occur. This would give the 74% stress value listed. This is a marginal area, and action needs to be taken only if an increase in overall equipment reliability is desired at this time.

Resistors R3, R4, and R5 on the inverter subassembly experience a power stress ratio of 95% during the gyro spin motor start-up phase. As a continuously operating level this ratio would be unacceptable, but as this condition will last for only 5 seconds, the thermal inertia of the parts will protect them from being put into a high reliability risk class. Statistics examined from similar applications of load resistors used in this manner (Lunar Orbiter IRU program) have not revealed any signs of a reliability problem, even when the stress ratio was more than double the ratio found in the RMP.

The relays on both relay cards, with the exception of K3 on card A, are all having their 12 volt coil circuits pulsed with a 22 volt 60 msec signal. The result of this usage is that during the pulses 2.31 watts are being dissipated instead of the nominal .65 watts. Power requirements for pull-in in the FLH and FCH coils are only .15 and .16 watts respectively. If any of these relays are operated repeatedly, a definite power problem exists which could bring about coil failures due to deterioration of the insulation due to excess heat. If the duty cycle is low, however, as information indicates, the heat problem is not a major consideration; but the stress in the windings, due to an over-voltage condition, could in time lead to an insulation breakdown. A look at the 24 volt counterpart of these relays shows that, with 22 volts applied, .538 watts will be expended in the FCH relay and .484 watts in the FLH relay compared with standard pull-in ratings of .160 and .150 watts respectively. In each case we would have over three times the necessary pull-in power. As an aiding factor these relays are rated to pull in in 3.5 msec, and we have 60 msec available. An additional aiding factor is that by drawing only $\frac{1}{4}$ the load current, the voltage pulse itself would be improved. For additional safety, if these higher voltage relays are used, a test condition should be set up whereby all coil resistances would be checked at Sperry to eliminate any relays with high coil resistance.

With regard to the Heater Controller Card, for the purposes of a reliability analysis at the level of development of MIL-HDBK-217A, 1 December 1965, the unijunction transistor 2N491A has been considered to be a silicon diode rated at less than 1 watt maximum power dissipation. The double emitter transistor 3N74 has been termed a silicon transistor, type NPN, rated at less than 1 watt maximum power dissipation.

4. Parts Application Analysis

As part of the stress analysis, the application of the parts was considered as well as the stress. No example of misapplication was found. Instances were found, as in the T/M Signal Conditioning Card, where electrolytic capacitors have their polarization reversed under specific conditions. It was found in all these cases, however, that diodes, where placed across these capacitors, limit this reverse voltage to less than one volt, which is permissible from a design viewpoint in all cases.

5. Failure Rate Analysis

The failure rates generated as a result of performing the stress analysis are presented in Table 3. The total failure rate (λ_T) given therein for the RMP (excluding gyro) can, under the assumptions given in the Scope and Magnitude of Effort section (2) of this report, be inverted to yield a mean-time-between-failures (MTBF), as shown below. While this number may be interesting as well as informative, its value is limited to the extent of the assumptions made in performing the analysis. Additional effort would be required to transform this figure into a more meaningful one which would take into consideration the operational functioning of the RMP and the environment encountered during those periods.

RMP Configuration	RMP Failure Rate* (λ_T) per 10^6 Hours	RMP MTBF* ($10^6/\lambda_T$) Hours
P/N 4310-90641-901 (SYG-4200 Gyro)	47.2528	21,163
P/N 4310-90641-903 (Kearfott Gyro)	46.7168	21,406

*Excluding gyro.

6. Worksheets

The Reliability Analysis Worksheets used in generating the data presented herein are included as part of this report.

Table 1

NIMBUS "D" STRESS PERCENTAGES

Power Conditioning Card (P/N 4216-67677D)

Ref. Desig.	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
C	50	50	34	34	24	24	20	46	19.8							
CR	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Q	10	10	10	10												
T	OK	OK														
R	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Ref. Desig.	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231
CR	10	10	10	10	10	10	10	10	10						
R	10	32.7	10	10	10	10	10	10	10	10	10	10	-	10	-

Heater Controller Card (P/N 4216-67678F)

Ref. Desig.	301	302	303	304	305	306	307	308	309	310	311	312	313	314
C	47.6	10.2	10	10	30	10	10	27.2	10/10	10				
L	OK													
T	OK	OK	OK											
CR			14.4	14.4										
Q	10	10	10	10	10	10	10	10						
R	-	10	10	10	10	10	10	10	10	10	10	10	10	-

Ref. Desig.	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329
R	10.5	39.2	10	-	10	10	10	10	10	10	10	-	10	10.1	10.1

Ref. Desig.	330	331	332	333	334
R	-	-	-	10	10

Table 1 (Continued)

Rate Loop Electronics Card (P/N 4216-67676C)

Ref. Desig.	101	102	103	104	105	106	107	108	109	110	111	112	113	114
C	10	16.6	10	48	48	13.3	13.3	17	23.2	10	23	10	10	
L	OK	OK												
T	OK	OK	OK	OK	OK									
CR	10	10	10	10	10	10	10	10	10	10	10			
Q	10	10	10	10	10	10	10	10	10	10	10			
R	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Ref. Desig.	115	116	117	118
R	10	10	10	-

R.F.I. Assembly (P/N 4310-90627A)

Ref. Desig.	0	1	2	3
C	35	70	50	50
L		OK		
R		22.2		

Inverter Subassembly (P/N 4216-67675D)

Ref. Desig.	1	2	3	4	5	6	7	8
C	45	45	22.4	50.8				
T	OK							
CR	10	10	10	10	10			
Q	10	10	10	10	10	10	10	
R			95.3*	95.3*	95.3*	10	10	10

*See Stress Analysis section of report for identification and discussion of these components.

Table 1 (Continued)

T/M Signal Conditioning Card (P/N 4216-67679C)

Ref. Desig.	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415
C	32	32	22.2	23.5	30	74*	10	10	12	33.8	34	41.6			
CR	10	10	10	10	10	10	10	10.8							
Q	10	54*													
R	-	10	10	-	10	10	-	10	10	10	10	10	10	10	10

Ref. Desig.	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430
R	10	-	-	10	10	10	10	10	18.5	10	10	-	10	13.3	-

Ref. Desig.	431	432	433	434	435	436	437
R	10	10	-	10	13.1	12	-

Relay Card A (P/N 4216-67680B)**

Ref. Iesig.	501	502	503	504	505	506	507	508	509	510	2	3	5	7
C	22.8													
CR	11.1	11.1	10	10	10	10	10	10	10	10				
K											10*	10	10*	10*

Relay Card B (P/N 4216-67681A)**

Ref. Desig.	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525
CR	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Ref. Desig.	526	527	528	1	4	6	8
CR	10	10	10				
K				20*	10*	20*	10*

*See Stress Analysis section of report for identification and discussion of these components.
**Used on RMP P/N 4310-90641-901 only.

Table 1 (Continued)

Relay Card A (P/N 4310-90848)**

Ref. Desig.	501	502	503	504	505	506	507	508	509	510	2	7
C	22.8											
CR	11.1	11.1	10	10	10	10	10	10	10	10		
K											10*	10*

Relay Card B (P/N 4310-90841)**

Ref. Desig.	511	512	513	514	515	516	517	518	519	520	521	522	525	526	527	528
CR	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Ref. Desig.	1	4	6	8
K	20*	10*	20*	10*

*See Stress Analysis section of report for identification and discussion of these components.
**Used on RMP P/N 4310-90641-903 only.

Table 2

SUMMARY OF COMPONENT STRESS LEVELS**

Stress Ratio %	% of Components Operating within Stress Level R		C		CR		K		Q	
0-10	87.0%	(94)	25.9%	(14)	93.7%	(74)	75%	(6)	97.0%	(31)
10-20	93.5	(7)	38.9	(7)	100	(5)	75		97.0	
20-30	95.2	(2)	59.3	(11)			100	(2)	97.0	
30-40	97.2		74.0	(8)					97.0	
40-50	97.2		87.0	(7)					97.0	
50-60	97.2		96.4	(5)					100	(1)*
60-70	97.2		96.4							
70-80	97.2		100	(2)*						
80-90	97.2									
90-100	100	(3)								

SUMMARY OF COMPONENT STRESS LEVELS***

Stress Ratio %	% of Components Operating within Stress Level R		C		CR		K		Q	
0-10	87.0%	(94)	25.9%	(14)	92.3%	(72)	66.7%	(4)	97.0%	(31)
10-20	93.5	(7)	38.9	(7)	100	(5)	66.7		97.0	
20-30	95.2	(2)	59.3	(11)			100	(2)	97.0	
30-40	97.2	(2)	74.0	(8)					97.0	
40-50	97.2		87.0	(7)					97.0	
50-60	97.2		96.4	(5)					100	(1)*
60-70	97.2		96.4							
70-80	97.2		100	(2)*						
80-90	97.2									
90-100	100	(3)								

*See Stress Analysis section of report for identification and discussion of these components.
**Used on RMP P/N 4310-90641-901 only.
***Used on RMP P/N 4310-90641-903 only.

Table 3

NIMBUS "D" RATE MEASURING PACKAGE
STRESSED FAILURE RATES/10^6 HOURS

Power Conditioning Card (P/N 4216-67677D)

	N		λ Inherent (Sum)		Total	
Capacitors						
Solid Electrolytic	6		.0146			
Jelled Electrolytic	3		.7600			
					.7746	.39
Diodes						
Sil. Rect.	21	7	2.1000	.35		
Sil. Zener	4		1.2000			
					3.3000	.35
Transistors						
Sil. NPN	1	0	.1000			
Sil. PNP Pwr.	3	1	1.2000			
					1.3000	.20
Transformers						
Audio Freq.	2		.4000		.4000	.20
Resistors						
Fixed Film	27	12	5.0400	.12		
Fixed Film Precision	3		.4500			
					5.4900	.12
Total					11.2646	1.26

Table 3 (Continued)

Heater Controller Card (P/N 4216-67678F)

	N	λ Inherent (Sum)	Total	
Capacitors				
Mylar	1	.0017		
Ceramic	5	.0250		
Solid Electrolytic	5	.0052		
			.0319	.02
Inductors				
Audio Freq.	1	.2000	.2000	.10
Transformers				
Audio Freq.	3	.6000	.6000	.30
Diodes				
Sil. Rect.	2	1.280		
Sil. Zener	1	.1940		
			1.4740	.74
Transistors				
Sil. NPN	5	.8170		
Sil. NPN (Med. Pwr.)	1	.2950		
Sil. NPN Double Emitter	1	.1580		
			1.2700	.63
Resistors				
Fixed Film	27	4.990 [illegible]	4.9900	.27
Total			8.5659	2.06

Table 3 (Continued)

Rate Loop Electronics (P/N 4216-676760)

	N	λ Inherent (Sum)		Total	
Capacitors					
Solid Electrolytic	8	.0140			
Mylar	2	.0020			
Ceramic	3	.0150			
				.0310	.02
Inductors					
Audio Freq.	2	.4000		.4000	.20
Transformers					
Audio Freq.	5	1.0000		1.0000	.50
Diodes					
Sil. Rect.	9	.9000			
Sil. Zener	2	.6000		1.5000	.75
Transistors					
Sil. PNP Pwr.	1	.4000			
Sil. NPN	3	.3000			
Sil. NPN Pwr.	7	1.4000			
				2.1000	1.05
Resistors					
Fixed Film	9	1.6650	.09		
Fixed Metal Film	8	1.2000	.01		
				2.8650	.10
Total				7.8960	2.62

RFI Assembly (P/N 4310-90627A)

	N	λ Inherent (Sum)		Total	
Capacitors					
Paper	1	.1170	.058		
Solid Electrolytic	2	.0088	.004		
Jelled Electrolytic	1	2.0000	.050		
				2.1258	.11
Inductors					
Audio Freq.	1	.2000		.2000	.10
Resistors					
Fixed Film (High Stab.)	1	.1600		.1600	.00
Total				2.4858	.21

Table 3 (Continued)

Inverter Subassembly (P/N 4216-67675D)

	N	λ Inherent (Sum)		Total	
Capacitors					
Paper	2	.4700	.2		
Mylar	1	.0010	-		
Electrolytic Jelled	1	.7200	.36		
				1.1910	.48
Transformers					
Audio Freq.	1	.2000		.2000	.10
Diodes					
Sil. Rect.	4	.4000			
Sil. Zener	1	.3000			
				.7000	.35
Transistors					
Sil. NPN Pwr.	7	1.4000		1.4000	.70
Resistors					
Fixed Film	3	.5550			
Fixed Film Precision	3	.6600			.63
				1.2150	
Total				4.7060	1.66

Table 3 (Continued)

<u>Telemetry Signal Conditioning Card (P/N 4216-67679C)</u>

	N	λ Inherent (Sum)	Total
Capacitors			
Solid Electrolytic	9	.0332	
Fixed Ceramic	2	.0100	
Mylar	1	.0010	
			.0442
Diodes			
Sil. Rect.	6	.6000	
Sil. Zener	2	.6000	
			1.2000
Transistors			
Sil. NPN	1	.1000	.1000
Integrated Circuits	1	.4000	.4000
Resistors			
Fixed Film	12	3.7030	
Fixed Metal Film	15	2.2640	
Variable Wirewound	1	1.0800	
			7.0470
Total			8.7912

<u>Relay Card A (P/N 4216-67680B)*</u>

	N	λ Inherent (Sum)	Total
Capacitors			
Fixed Ceramic	1	.0053	.0053
Diodes			
Sil. Rect.	10	1.2520	1.2520
Relays			
Latching	3	.4530	
Non-latching	1	.1510	
			.6040
Total			1.8613

*Used on RMP P/N 4310-90641-901 only.

Table 3 (Continued)

Relay Card B (P/N 4216-67681A)*

	N	λ Inherent (Sum)	Total
Diodes	18	2.0780	2.0780
Relays			
Latching	2	.3020	
Non-latching	2	.3020	
			.6040
Total			2.6820

Relay Card A (P/N 4310-90848)**

	N	λ Inherent (Sum)	Total
Capacitors			
Fixed Ceramic	1	.0053	.0053
Diodes			
Sil. Rect.	10	1.2520	1.2520
Relays			
Latching	1	.1510	
Non-latching	1	.1510	
			.3020
Total			1.5593

Relay Card B (P/N 4310-90841)**

	N	λ Inherent (Sum)	Total
Diodes	16		1.8440
Relays			
Latching	2	.3020	
Non-latching	2	.3020	
			.6040
Total			2.4480

*Used on RMP P/N 4310-90641-901 only.
**Used on RMP P/N 4310-90641-903 only.

Table 3 (Continued)

Grand Total, λ_T (Failures/10^6 Hours)

(1)	RMP P/N 4310-90641-901 (SYG-4200 Gyro configuration)	-	47.2528*
(2)	RMP P/N 4310-90641-903 (Kearfott Gyro configuration)	-	46.7168*

*Excluding Gyro.

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ____________ P/N ____________ REV. ____ NOTES: ____________

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

CKT. SYM.	P/N	TYPE	MFR.	RATINGS: VALUE MFD	RATINGS: TOL. %	RATINGS: VOLTS	RATINGS: ADD'L. (SPECIFY)	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED VOLTS	OPERATING CONDITIONS: ADD'L.	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
C201	337622-30	SOLID ELECTROL		2.2	10	20		10	50		45°		MIL 217A FIG 7A.3A8	.004A
C202	337622-30	SOLID ELECTROL		2.2	10	20		10	50					.0044
C203	337622-85	SOLID ELECTROL		4.7	10	50		17	34					.0019
C204	337622-85	SOLID ELECTROL		4.7	10	50		17	34					.0019
C205	4310-10253	ELECTROL JELLED		47	20	50		12	24				MIL 217A FIG 7A.7B	.100
C206	4310-10253	ELECTROL JELLED		47	20	50		12	24					.100
C207	337622-38	SOLID ELECTROL		47	10	20		4	20				MIL 217A FIG 7A.3A8	.0010
C208	4310-10253	ELECTROL JELLED		47	20	50		23	46				MIL 217A FIG 7A.7B	.56
C209	337622-30	SOLID ELECTROL		2.2	10	20		3.96	19.8				MIL 217A FIG 7A.3A8	.0010

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

Ckt. Sym.	P/N	Type	Mfr.	Maximum Ratings (Pwr, Volt, Curr) Parameter (Specify)	Value	% Du Cy	@ TA or TC °C	Operating Conditions P Value	% Du Cy	TA or TC Range °C	% of Rated	Remarks	Inherent Failure Rate Source	Units
CR 201	632281-1	Sil. IN645		PA VR	600mw 225V		TA = 25°C	.4 mw	50		<10	ΘJA = 0.33°C/mw	MIL 217 A FIG 7.13	.100
CR202	632281-1	Sil IN645		PA VR	600mw 225V			1 mw	50		<10			.100
CR203	632281-1	Sil IN645		PA VR	600mw 225V			.32 mw	50		<10			.100
CR204	632281-1	Sil IN645		PA VR	600mw 225V			3.87 mw	50		<10			.100
CR205	632281-1	Sil IN645		PA VR	600mw 225V			3.87 mw	50		<10			.100
CR206	632281-1	Sil IN645		PA VR	600mw 225V			—	—		<10			.100
CR207	632281-1	Sil IN645		PA VR	600mw 225V			—	—		<10			.100
CR208	632281-1	Sil IN645		PA VR	600mw 225V			—	—		<10			.100
CR209	632281-1	Sil IN645		PA VR	600mw 225V			—	—		<10			.100
CR210	632638-111	Sil IN756A Zener		PA VR	400mW 8.2V			9 mw			<10	ΘJA = 0.3125°C/mw		.300
CR211	632638-105	Sil IN750A Zener		PA VR	400mw 4.7V			1.13 mw			<10	ΘJA = 0.3125°C/mw		.300
CR212	632631-101	Sil IN746A Zener		PA VR	400mw 3.3V			—	50		<10	ΘJA = 0.3125°C/mw		.300
CR213	632281-1	Sil IN645		PA VR	600mw 225V			—			<10	ΘJ-A = 0.33°C/mw		.100
CR214	632281-1	Sil IN645		PA VR	600mw 225V		✓	—	50	✓	<10	ΘJ-A = 0.33°C/mw	✓	.100

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

CKT. SYM.	P/N	TYPE	MFR.	MAXIMUM RATINGS (PWR, VOLT, CURR) PARAMETER (SPECIFY)	VALUE	% DU CY	θ TA OR TC °C	OPERATING CONDITIONS P VALUE	% DU CY	TA OR TC RANGE °C	% OF RATED	REMARKS	FAILURE RATE SOURCE	UNITS
CR215	632386-1	SIL IN691		P_A V_R	400mW 75V		TA 25°C	.12 MW		45	<10	θ_{J-A} = 0.375°C/mW	MIL 217A FIG 7.9.3	.100
CR216	632386-1	SIL IN691		P_A V_R	400mW 75V			.12 MW			<10			.100
CR217	632386-1	SIL IN691		P_A V_R	400mW 75V			.12 MW			<10			.100
CR218	632386-1	SIL IN691		P_A V_R	400mW 75V			—			<10			.100
CR219	632386-1	SIL IN691		P_A V_R	400mW 75V			—			<10			.100
CR220	632386-1	SIL IN691		P_A V_R	400mW 75V			—			<10			.100
CR221	632788-106	SIL IN967B ZENER		P_A V_R	400mW 18V			7.8 MW			<10	θ_{J-A} = 0.375°C/mW		.300
CR222	632291-1	SIL IN645		P_A V_R	600mW 225V			.12 MW			<10	θ_{J-A} = 0.33°C/mW		.100
CR223	632291-1	SIL IN645		P_A V_R	600mW 225V			.12 MW			<10			.100
CR224	632281-1	SIL IN645		P_A V_R	600mW 225V			—			<10			.100
CR225	632291-1	SIL IN645		P_A V_R	600mW 225V			.8 MW			<10			.100

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ___ NOTES: ______

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

				Maximum Ratings (Pwr, Volt, Curr)				Operating Conditions					Failure Rate	
Ckt. Sym.	P/N	Type	Mfr.	Parameter (Specify)	Value	% Du Cy	@ TA or TC °C	P Value	% Du Cy	TA or TC Range °C	% of Rated	Remarks	Source	Units
Q201	336546	Sil 2N930 NPN		PA	300mw		25°C	.45 mw	100	45	<10	ΘJA = 0.5°C/mw	MIL 217A Fig 7.4.4.8	.100
Q202	337503-1	Sil 2N2907 PNP Med Pwr		Pc	1.8w			3.45 mw	50		<10	ΘJC = .097°C/mw		.400
Q203	337503-1	Sil 2N2907 PNP Med Pwr		Pc	1.8w			.12 mw	25		<10			.400
Q204	337503-1	Sil 2N2907 PNP Med Pwr		Pc	1.8w			3.45 mw	50		<10			.400

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ________ P/N ________ REV. ____ NOTES: ________

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

CKT. SYM	P/N	TYPE	MFR.	RATINGS: VALUE OHMS	RATINGS: TOL %	RATINGS: POWER WATTS	RATINGS: VOLTS	OPERATING CONDITIONS: POWER WATTS	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED POWER	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
R201	334711-91	FIXED FILM		56K	2%	1/4 W	250	43.7 MW	49.5	<10	45	50 % DUTY CYCLE	217A FIG 7.5.13B	.185
R202	334711-25			100				—	—	<10				.185
R203	334711-82			24K				3.6 MW	9.3	<10				.185
R204	334711-81			22K				25.8 MW	23.8	10				.185
R205	334711-83			27K				10.7 MW	17	<10		50 % DUTY CYCLE		.185
R206	334711-25			100				—	—	<10				.185
R207	334711-73			10K				52.8 MW	23	21.2				.185
R208	334711-83			27K				22.1 MW	24.5	<10				.185
R209	334711-97			100K				.005 MW	.7	<10				.185
R210	334711-83			27K				.75 MW	4.5	<10		25 % DUTY CYCLE		.185
R211	334711-83			27K				.75 MW	4.5	<10		25 % DUTY CYCLE		.185
R212	334711-93			27K				—	.7	<10				.185
R213	632975-208	FIXED FILM PRECISION		12.1	1%	1/8		—	—	<10		NO STEADY STATE CURRENT	MIL 217A FIG 7.5[illegible]	.15
R214	632975-2[illegible]			12.1	1%	1/8		—	—	<10				.15

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Power Conditioning Card P/N 4216-67677 REV. D

CKT SYM	P/N	TYPE	MFR.	RATINGS: VALUE OHMS	RATINGS: TOL %	RATINGS: POWER WATTS	RATINGS: VOLTS	OPERATING CONDITIONS: POWER WATTS	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED POWER	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
R215	334711-25	Fixed Film		100	2	1/4	250	—	—	<10	45		217A F.G. 7.5.13B	.145
R216	334711-59	Fixed Film		2.7K	2	1/4	250	3.3 mW	3	<10				.195
R217	632975-208	Fixed Film Precision		12.1	1	1/8		—	33 mV	<10			MIL 217A Fig 7.5.9B	.15
R218	334711-57	Fixed Film		2.2K	2	1/4	250	164 mW	19	32.7		50% Duty Cycle	MIL 217A Fig 7.5.13B	.23
R219	334711-61			3.3K				.15 mW	.7	<10				.185
R220	334711-73			10K				—	—	<10				.185
R221	334711-81			22K				.63 mW	3.7	<10				.185
R222	334711-65			4.7K				.884 mW	2.04	<10				.185
R223	334711-70			7.5K				1.42 mW	3.26	<10				.185
R224	334711-97			100K				5.55 mW	23.6	<10				.185
R225	334711-97			100K				.57 mW	24	<10				.185
R226	334711-97			100K				.57 mW	24	<10				.185
R227	334711-57			2.2K				—	—	<10				.185
R228	334711-57			2.2K				—	—	<10				.185
R229	334711-59			2.7K				0	0	0		Only used to limit shorted test point		.185
R230	334711-25			100				—	—	<10				.185
R231	334711-59			2.7K				—	—	0		[illegible]		0

RELIABILITY ANALYSIS WORK SHEET - INDUCTIVE DEVICES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Power Conditioning P/N 4216-67677 REV. D

Ckt. Sym.	P/N	Type	Mfr.	Ratings: Temp. Class	Ratings: Winding (Specify)	Ratings: Volt	Ratings: Curr	Ratings: Temp. Rise °C	Operating Conditions: Amb. Temp	Operating Conditions: Volt	Operating Conditions: Curr	Operating Conditions: % Du Cy	Operating Conditions: Temp Rise °C	Remarks	Failure Rate: Source	Failure Rate: Units
T201	337160-139	DO T39		R Grade 4		64				18					MIL 217A FIG 7.7.28	.20
T202	337160-136	DO-T36		R Grade 4		64				4						.20

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Heater Controller Card P/N 4216-67678 REV. F

				Ratings				Operating Conditions					Failure Rate	
Ckt. Sym	P/N	Type	Mfr.	Value MFD	Tol %	Volts	Add'l. (Specify)	Volts	% Oper. to Rated Volts	Add'l.	Amb. Temp °C	Remarks	Source	Units
C301	337714-1	Mylar		.0169	2	50		23.8	47.6		45		217A FIG 7.6.33B	.0017
C302	337622-73	Electrol Tant		.47	10	50		5.1	10.2		45		217A FIG 7.6.36B	.0008
C303	337622-85	Electrol Tant		4.7	10	50		5	10		45		217A FIG 7.6.36B	.0008
C304	337622-85	Electrol Tant		4.7	10	50		5	10		45		217A FIG 7.6.36B	.0008
C305	337622-85	Electrol Tant		4.7	10	50		15	30		45		217A FIG 7.6.36B	.0015
C306	1784532-29	Ceramic Style CK		.01	10	200		10.8	5.4		45		217A FIG 7.24A	.0050
C307	1784532-29	Ceramic Style CK		.01	10	200		6.8	3.4		45		217A FIG 7.24A	.0050
C308	337622-30	Electrol Tant		2.2	10	20		5.45	27.2		45		217A FIG 7.6-36B	.0013
C309 A	1784532	Ceramic		478 pf. 2200 pf.	10	200		4.95	2.4		45		217A FIG 7.6-24B	.0050
C309 B	1784532	Ceramic		476 pf 2200 pf	10	200		4.95	2.4		45		217A FIG 7.6-24B	.0050
C310	1784532-29	Ceramic Style CK		.01	10	200		5.9	2.95		45		217A FIG 7.6-24B	.0050

RELIABILITY ANALYSIS WORK SHEET - INDUCTIVE DEVICES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Heater Controller Card P/N 4216-67678 REV. F

				Ratings					Operating Conditions						Failure Rate	
Ckt. Sym.	P/N	Type	Mfr.	Temp. Class	Winding (Specify)	Volt	Curr	Temp Rise °C	Amb. Temp	Volt	Curr	% Du Cy	Temp Rise °C	Remarks	Source	Units
L301	33731/6					50				—					Mil 217A FIG 7.73A	.20
T301	337160-137					28.4				3.5					Mil 217A FIG 7.72	.20
T302	337160-52					40				3.5					217A FIG 7.72B	.20
T303	337160-136					64				8.5					217A FIG 7.72B	.20

RELIABILITY ANALYSIS WORK SHEET – ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC Heater Controller Card P/N 4216-67678 REV. F

CKT. SYM.	P/N	TYPE	MFR.	Maximum Ratings (Pwr, Volt, Curr): Parameter (Specify)	Value	% Du Cy	@ TA or TC °C	Operating Conditions: P Value	% Du Cy	TA or TC Range °C	% of Rated	Remarks	Failure Rate: Source	Units
CR303	632638-109	SIL Zener 1N754A		P(AIR) V_Z	400mw 6.8v		25	48.4 mw		45	14.4	θ_{JA} = .3125 °C/mw	217A Fig7.43B	.640
CR304	632638-109	SIL Zener 1N754A		P(AIR) V_Z	400mw 6.8v		25	48.4 mw		45	14.4	θ_{JA} = .3125 °C/mw	217A Fig7.43B	.640
Q301	336546	SIL NPN 2N930		P(AIR)	300 mw		25	.24mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.157
Q302	336546	SIL NPN 2N930		P(AIR)	300 mw		25	1.98mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.160
Q303	336546	SIL NPN 2N930		P(AIR)	300mw		25	12.5mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.180
Q304	632655-108	UJT SIL 2N491A		P(AIR)	450mw		25	10.73 mw		45	<10	θ_{JA} = .2563°C/mw	217A Fig7.43A	.194
Q305	336546	SIL NPN 2N930		P(AIR)	300 mw		25	.34mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.157
Q306	336546	SIL NPN 2N930		P(AIR)	300 mw		25	5.1mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.163
Q307	337634	SIL NPN 2N910		P_C	1.8mw		25	1.5mw		45	<10	θ_{JC} = .097°C/mw	217A Fig7.44B	.295
Q308	337198-1	DIL NPN Double Emitter 3N74		P_T	300mw		25	.75mw		45	<10	θ_{JA} = .5°C/mw	217A Fig7.44B	.158

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ____________ P/N ____________ REV. ____ NOTES: ____________

SCHEMATIC Heater Controller Card P/N 4216-67678 REV. F

				Ratings				Operating Conditions					Failure Rate	
Ckt. Sym	P/N	Type	Mfr.	Value Ohms	Tol %	Power Watts	Volts	Power Watts	Volts	% Oper. to Rated Power	Amb. Temp °C	Remarks	Source	Units
R301	334711-89	Fixed Film		47K	2	1/4	250	0	0	0	45	To test point	217A FIG7513B	—
R302	632375-348			348Ω	1	1/8		2.48 mw	.545v	1.8			217A FIG7598	.15
R303	632375-392			1K	1	1/8		6.09 mw	2.48v	4.85			217A FIG7598	.15
R304	334711-97			100K	2	1/4		1.32 mw	11.5v	<10			217A FIG7513B	.185
R305	334711-79			18K	2	1/4		6.13 mw	10.5v	<10				.185
R306	334711-101			150K	2	1/4		.735 mw	10.5v	<10				.185
R307	334711-83			27K	2	1/4		2.67 mw	3.5v	<10				.185
R308	334711-73			10K	2	1/4		.4 mw	2v	<10				.185
R309	334711-69			6.8K	2	1/4		—	.2v	<10				.185
R310	334711-53			1.5K	2	1/4		.5 mw	.875v	<10				.185
R311	334711-53			1.5K	2	1/4		.5 mw	.815v	<10				.185
R312	334711-83			27K	2	1/4		.36 mw	3.1v	<10				.185
R313	334711-53			1.5K	2	1/4		1.65 mw	1.57v	<10				.185
R315	632375-			475K 47.5K	1	1/8		13.15 mw	7.9v	10.5			217A FIG7598	.15
R316	632375-424			2.15K	1	1/8		49 mw	10.28v	39.2			217A FIG7598	.17
R317	632375-515			19.1K	1	1/8		8.53 mw	12.78	<10			217A FIG7598	.15
R319	334711-83			27K	2	1/4		3.63 mw	9.8v	<10			217A FIG7513B	.185
R320	334711-83			27K	2	1/4		.671 mw	4.26v	<10			FIG7513B	.185

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC Heater Controller Card P/N 4216-67678 REV. F

CKT. SYM	P/N	TYPE	MFR.	RATINGS: VALUE OHMS	RATINGS: TOL %	RATINGS: POWER WATTS	RATINGS: VOLTS	OPERATING CONDITIONS: POWER WATTS	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED POWER	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
R321	334711-67	Fixed Film		5.6K	2	1/4W	250	.139 mw.	.185v	<10	45		MIL-217A F167513B	.185
R322	334711-101	Fixed Film		150K	2	1/4W	250	1.15 mw	13.3v	<10	45			.185
R323	334711-73	Fixed Film		10K	2	1/4W	250	17.7 mw	13.3v	<10	45			.185
R324	334711-41	Fixed Film		470Ω	2	1/4W	250	1.05 mw.	.7v	<10	45			.185
R325	334711-97	Fixed Film		100K	2	1/4W	250	3.07 mw.	17.5v	<10	45			.185
R326	334711-25	Fixed Film		100Ω	2	1/4W	250	0	0	0	45	To test point		0
R327	334711-83	Fixed Film		27K	2	1/4W	250	.84 mw.	4.76v	<10	45			.185
R328	334711-65	Fixed Film		4.7K	2	1/4W	250	25.3 mw.	10.9v	10.1	45			.185
R329	334711-65	Fixed Film		4.7K	2	1/4W	250	25.3 mw.	10.9v	10.1	45			.185
R330	334711-73	Fixed Film		1K	2	1/4W	250	0	0	0	45	To test point		0
R331	334711-59	Fixed Film		2.7K	2	1/4W	250	0	0	0	45	To test point		0
R332	334711-59	Fixed Film		2.7K	2	1/4W	250	0	0	0	45	To test point		0
R314	632-375-296	Fixed Film		10MΩ	1	1/8W	250	6.36 mw	.252v	<10	45		217A F167598	.15
R333	334711-	Fixed Film		2K to 36K	2	1/4W	250	.245 mw	.728v	<10	45		217A F167513B	.185
R334	334711-	Fixed Film		2K to 36K	2	1/4W	250	.294 mw	.234v	<10	45		217A F167513B	.185

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC RATE LOOP ELECTRONICS CARD P/N 4216-67676 REV. C

CKT. SYM	P/N	TYPE	MFR.	RATINGS VALUE MFD	RATINGS TOL %	RATINGS VOLTS	RATINGS ADD'L (SPECIFY)	OPERATING CONDITIONS VOLTS	OPERATING CONDITIONS % OPER. TO RATED VOLTS	OPERATING CONDITIONS ADD'L	OPERATING CONDITIONS AMB. TEMP °C	REMARKS	FAILURE RATE SOURCE	FAILURE RATE UNITS
C101	337622-73	SOLID ELECTROL		0.47	10	50		.1	<10		45		MIL 217A FIG 7.6.36B	.0005
C102	337714-1	MYLAR		.0169	1	50		8.3	16.6				MIL 217A FIG 7.6.33B	.0010
C103	337622-30	SOLID ELECTROL		22	10	20		2	10				MIL 217A FIG 7.6.36B	.0005
C104	337622-91	SOLID ELECTROL		15	10	50		24	48				MIL 217A FIG 7.6.36B	.0043
C105	337622-91	SOLID ELECTROL		15	10	50		24	48				MIL 217A FIG 7.6.36B	.0043
C106	337622-22	SOLID ELECTROL		22	10	15		2	13.3				MIL 217A FIG 7.6.36B	.0008
C107	337622-22	SOLID ELECTROL		22	10	15		2	13.3				MIL 217A FIG 7.6.36B	.0008
C108	337714-1	MYLAR		.0169	1	50		8.5	17				MIL 217A FIG 7.6.33B	.0010
C109	337622-73	SOLID ELECTROL		0.47	10	50		11.6	23.2				MIL 217A FIG 7.6.36B	.0011
C110	178453?-1	CERAMIC		47PF	10	200		10.2	<10				MIL 217A FIG 7.6.24B	.0050
C111	337622-10	SOLID ELECTROL		47	10	10		2.3	23				MIL 217A FIG 7.6.36B	.0011
C112	1784532-15	CERAMIC		680PF	10	200		3.1	<10				MIL 217A FIG 7.6.24B	.0050
C113	1784532-15	CERAMIC		680PF	10	200		12	<10				MIL 217A FIG 7.6.24B	.0050

RELIABILITY ANALYSIS WORK SHEET - INDUCTIVE DEVICES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC RATE LOOP ELECTRONICS P/N 4216-67676 REV. C

CKT. SYM.	P/N	TYPE	MFR.	RATINGS TEMP. CLASS	WINDING (SPECIFY)	ARI VOLT	CURR	TEMP. RISE °C	OPERATING CONDITIONS AMB. TEMP	VOLT	CURR	% DU CY	TEMP RISE °C	REMARKS	FAILURE RATE SOURCE	UNITS
L101	337316	REACTOR		R		50				5.6	2MA				MIL 217A FIG 7.22.1	.20
L102	337316	REACTOR		R		50				—	.65MA					.20
T101	337160-137			R		20A				5.6					MIL 217A FIG 7.22B	.20
T102	337160-137			R		20A				17						.20
T103	337160-137			R		20A				2.1						.20
T104	337160-137			R		20A				2.1						.20
T105	337160-142			R		28				6.4						.20

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC RATE LOOP ELECTRONICS P/N 4216-67676 REV. C

CKT. SYM.	P/N	TYPE	MFR.	Maximum Ratings (Pwr, Volt, Curr): Parameter (Specify)	Value	% Du Cy	@ T_A or T_C °C	Operating Conditions: P Value	% Du Cy	T_A or T_C Range °C	% of Rated	Remarks	Failure Rate: Source	Units
CR101	632281-1	SIL 1N645		P (AIR) V_R	600 MW 225 V		25	5 MW		45	40	θ_{JA} = 0.33 °C/MW	MIL 217A FIG 7A36	.100
CR102	632386-1	SIL 1N691		P (AIR) V_R	400 MW 75 V			2.8 MW	50		40	θ_{JA} = 0.375 °C/MW		.100
CR103	632386-1	SIL 1N691		P (AIR) V_R	400 MW 75 V			2.8 MW	50		40			.100
CR104	632386-1	SIL 1N691		P (AIR) V_R	400 MW 75 V			2.8 MW	50		40			.100
CR105	632386-1	SIL 1N691		P (AIR) V_R	400 MW 75 V			2.8 MW	50		40			.100
CR106	632281-1	SIL 1N645		P (AIR) V_R	600 MW 225 V			.33 MW			40	θ_{JA} = 0.33 °C/MW		.100
CR107	632281-1	SIL 1N645		P (AIR) V_R	600 MW 225 V			.33 MW			40			.100
CR108	632281-1	SIL 1N645		P (AIR) V_R	600 MW 225 V			—			40			.100
CR109	632281-1	SIL 1N645		P (AIR) V_R	600 MW 225 V			—			40			.100
CR110	632768-109	SIL 1N910B ZENER		P (AIR) V_{RZ}	400 MW 24 V			—			40	θ_{JA} = 0.375 °C/MW		.300
CR111	632768-109	SIL 1N910B ZENER		P (AIR) V_{RZ}	400 MW 24 V			—			40			.300
Q101	336 546	2N910 SIL NPN		P (AIR)	300 MW			9 MW			40	θ_{JA} = 0.5 °C/MW	MIL 217A FIG 7A4B	.100
Q102	[illegible]	2N2907 MED PWR PNP		P_C	1.8 W.			20 MW			40	θ_{JC} = .191 °C/MW		.400

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC RATE LOOP ELECTRONICS P/N 4216-67676 REV. C

CKT. SYM.	P/N	TYPE	MFR.	MAXIMUM RATINGS (PWR, VOLT, CURR) PARAMETER (SPECIFY)	VALUE	% DU CY	@ TA OR TC °C	OPERATING CONDITIONS P VALUE	% DU CY	TA OR TC RANGE °C	% OF RATED	REMARKS	FAILURE RATE SOURCE	UNITS
Q103	337634	2N910 SIL NPN		P_c	1.8W		25	240 MW	50	45	<10	θ_{JC} = .097°C/MW	MIL 217A FIG 7.4.4B	.200
Q104	337634	2N910 SIL NPN						240 MW	50		<10			.200
Q105	337634	2N910 SIL NPN						5.6 MW	50		<10	SAT & CUTOFF		.200
Q106	337634	2N910 SIL NPN						5.6 MW	50		40			.200
Q107	337634	2N910 SIL NPN						5.6 MW	50		<10			.200
Q108	337634	2N910 SIL NPN						5.6 MW	50		<10			.200
Q109	336546	2N930 SIL NPN		P (AIR)	300MW			—	50		<10	θ_{JA} = 0.5 °C/MW		.100
Q110	337503-1	2N2907 SIL PNP MED PWR		P_c	1.8W			—	50		40	θ_{JC} = .097 °C/MW		.100
Q111	336546	2N930 SIL NPN		P (AIR)	300MW			9.5 MW			<10	θ_{JA} = 0.5°C/MW		.100

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ____________ P/N ____________ REV. ____ NOTES: ____________

SCHEMATIC RATE LOOP ELECTRONICS P/N 4216-62676 REV. C

CKT SYM	P/N	TYPE	MFR.	RATINGS VALUE OHMS	RATINGS TOL %	RATINGS POWER WATTS	RATINGS VOLTS	OPERATING CONDITIONS POWER WATTS	OPERATING CONDITIONS VOLTS	OPERATING CONDITIONS % OPER. TO RATED POWER	OPERATING CONDITIONS AMB. TEMP °C	REMARKS	FAILURE RATE SOURCE	FAILURE RATE UNITS
R101	334711-82	FIXED FILM		24K	2	1/4	250	.325 MW	3	<10	45		MIL 217A FIG 7.5.13B	.185
R102	334711-91	FIXED FILM		56K	2	1/4	250	1.45 MW	9	<10				.185
R103	632375-328	METAL FILM		215	1	1/8	250	—	—	<10			MIL 217A FIG 7.5.9B	.15
R104	632375-520	METAL FILM		21.5K	1	1/8	250	1.5 MW	5.7	<10				.15
R105	334711-81	FIXED FILM		22K	2	1/4	250	25 MW	23	10			MIL 217A FIG 7.5.13B	.185
R106	632375-268	METAL FILM		51.1	1	1/8	250	5 MW	.5	<10			MIL 217A FIG 7.5.9B	.15
R107	632375-268	METAL FILM		51.1	1	1/8	250	5 MW	.5	<10				.15
R108	334711-53	FIXED FILM		1.5K	2	1/4	250	11.8 MW	4.2	<10			MIL 217A FIG 7.5.13B	.185
R109	334711-53	FIXED FILM		1.5K	2	1/4	250	3 MW	2.1	<10				.185
R110	334711-18	FIXED FILM		51	2	1/4	250	—	—	<10				.185
R111	632375-513	METAL FILM		18.2K	1	1/8	250	7.65 MW	11.8	<10			MIL 217A FIG 7.5.9B	.15
R112	632375-498	METAL FILM		12.7K	1	1/8	250	5.36 MW	8.25	<10				.15
R113	632375-480	METAL FILM		8.25K	1	1/8	250	.0194 MW	.4	<10				.15
R114	632375-472	METAL FILM		6.81K	1	1/8	250	.0235 MW	.4	<10				.15
R115	334711-73	FIXED FILM		10K	2	1/4	250	.9 MW	3	<10			MIL 217A FIG 7.5.13B	.185
R116	334711-49	FIXED FILM		1K	2	1/4	250	[illegible]	2.3	<10				.185
R117	334711-25	FIXED FILM		100	2	1/4	250	2.5 MW	.5	<10				.185
R118	334711-59	FIXED FILM		2.7K	2	1/4	250	0	0	0		TO TEST POINT (PROTECTION)		0

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY RFI ASSEMBLY P/N 4310-90627 REV. A NOTES:

SCHEMATIC ______ P/N ______ REV. ______

				Ratings				Operating Conditions					Failure Rate	
Ckt. Sym.	P/N	Type	Mfr.	Value MFD	Tol %	Volts	Add'l. (Specify)	Volts	% Oper. to Rated Volts	Add'l.	Amb. Temp °C	Remarks	Source	Units
C	(PART OF FL 1)	PAPER		.42		100		35	35		45	FOR SHORT TIME ONLY IN CASE OF S/C MALFUNCTION	MIL 217A FIG7.6.98	.117
C1	4310-10253	JELLED ELECTROL		47	20	50		35	70				MIL217A FIG7.6.176	2.0
C2	337622-91	SOLID ELECTROL		15	10	50		25	50				MIL217A FIG7.6.368	.0044
C3	337622-91	SOLID ELECTROL		15	10	50		25	50					.0044

RELIABILITY ANALYSIS WORK SHEET - INDUCTIVE DEVICES

ASSEMBLY FLI- RFI ASSEMBLY P/N 4310-40627 REV. A NOTES: ______

SCHEMATIC ______ P/N ______ REV. ______

				Ratings					Operating Conditions						Failure Rate	
Ckt. Sym.	P/N	Type	Mfr.	Temp. Class	Winding (Specify)	Volt	Curr	Temp. Rise °C	Amb. Temp	Volt	Curr	% Du Cy	Temp Rise °C	Remarks	Source	Units
L1	(PART OF FL1)	INDUCTOR				–	–			–	–			(.85MH)(.3A)	MIL 217A Fig 7.7.28	.20

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY RFI ASSEMBLY P/N 430-90627 REV. A NOTES:

SCHEMATIC P/N REV.

				Ratings				Operating Conditions					Failure Rate	
Ckt Sym	P/N	Type	Mfr.	Value Ohms	Tol %	Power Watts	Volts	Power Watts	Volts	% Oper. to Rated Power	Amb. Temp °C	Remarks	Source	Units
R1	632 235-464	Fixed Film High Stability		5.62K	1	1/2	—	111 MW	25	22.2	45		MIL 217A P6-7508	.16

B

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC INVARTER SUBASSY P/N 4216-67675 REV. D

CKT. SYM.	P/N	TYPE	MFR.	RATINGS: VALUE MFD	RATINGS: TOL %	RATINGS: VOLTS	RATINGS: ADD'L. (SPECIFY)	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED VOLTS	OPERATING CONDITIONS: ADD'L.	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
C1	0645-83	PAPER		.82	10	100		45	45		45		MIL 217A FIG 7.6 [illegible]	.235
C2	0645-08	PAPER		.47	10	100		45	45				MIL 217A FIG 7.6 [illegible]	.235
C3	337633-26	MYLAR		1.5	10	50		11.2	22.4				MIL 217A FIG 7.6.33B	.0010
C4	4310-10253	ELECTAL (JELLY)		47	20	50		25.4	50.8				MIL 217A FIG 7.6.7B	.72

RELIABILITY ANALYSIS WORK SHEET - INDUCTIVE DEVICES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC INVERTER SUBASSY P/N 4216-67675 REV. D

				RATINGS					OPERATING CONDITIONS						FAILURE RATE	
CKT. SYM.	P/N	TYPE	MFR.	TEMP. CLASS	WINDING (SPECIFY)	VOLT	CURR	TEMP RISE °C	AMB. TEMP	VOLT	CURR	% DU CY	TEMP RISE °C	REMARKS	SOURCE	UNITS
T1	337713		MAGNETICO	TP5 RX		582	.35A			28.5					MIL 217A FIG 7.2.1	.20

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC INVERTER SUB- P/N 421 6-67675 REV. D

				Maximum Ratings (Pwr, Volt, Curr)				Operating Conditions					Failure Rate	
Ckt. Sym.	P/N	Type	Mfr.	Parameter (Specify)	Value	% Du Cy	@ TA or TC °C	P Value	% Du Cy	TA or TC Range °C	% of Rated	Remarks	Source	Units
CR1	632386-1	SIL 1N691		P (AIR) V_R	400MW 75V		25	1MW		45	40	θ_{JA} = 0.375 °C/MW	MIL 217A FIG 7.4.3B	.100
CR2	632386-1	SIL 1N691		P (AIR) V_R	400MW 75V			1 MW			<10			.100
CR3	632386-1.	SIL 1N691		P(AIR) V_R	400MW 75V			—	—		<10			.100
CR4	632386-1	SIL 1N691		P (AIR) V_R	400MW 75V			—	-		<10			.100
CR5	632788-109	SIL 1N970B ZENER		P (AIR) V_{RZ}	400MW 24V			—			<10			.300
Q1	337375	SIL NPN POWER 2N1724		P_C P_A	50W 3W		T_C = 100°C T_A = 25°C	—			<10	θ_{JC} = 1.5°C/W θ_{JA} = 50°C/W	MIL 217A FIG 7.4.4B	.200
Q2	337375	SIL NPN POWER 2N1724		P_C P_A	50W 3W		T_C = 100°C T_A = 25°C	—			<10			.200
Q3	337375	SIL NPN POWER 2N1724		P_C P_A	50W 3W		T_C = 100°C T_A = 25°C	.76 MW			<10	θ_{JC} = 1.5 °C/W θ_{JA} = 50°C/W		.200
Q4	337375	SIL NPN POWER 2N1724		P_C P_A	50W 3W		T_C = 100°C T_A = 25°C	.6W			<10	θ_{JC} = 1.5 °C/W θ_{JA} = 50°C/W		.200
Q5	337634	2N910 SIL NPN		P_C	1.8W		25	2 MW			<10	θ_{JC} = .097°C/MW 50% DUTY CYCLE		.200
Q6	337634	2N910 SIL NPN		P_C	1.8W			2 MW			<10	50% DUTY CYCLE		.200
Q7	337503-1	2N2907 SIL PNP MED PWR		P_C	1.8W			2.2 MW			<10			.240

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC INVERTER SUB ASSY P/N 4216-67675 REV. D

CKT SYM	P/N	TYPE	MFR.	RATINGS: VALUE OHMS	RATINGS: TOL %	RATINGS: POWER WATTS	RATINGS: VOLTS	OPERATING CONDITIONS: POWER WATTS	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED POWER	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
R3	632975-208	FIXED FILM RESISTOR		12.1	1	1/8		119MW 194MW	1.2 .484	95.3 15.5	45	FOR 5 SEC ONLY NORMALLY	MIL 217A FIG 7.5.9B	.22 .155
R4	632975-208			12.1	1	1/8		119MW 194MW	1.2 .484	95.3 15.5		FOR 5 SEC ONLY NORMALLY		.22 .155
R5	632975-208			12.1	1	1/8		119MW 194MW	1.2 .484	95.3 15.5		FOR 5 SEC ONLY NORMALLY		.22 .155
R6	334711-41	FIXED FILM		470	2	1/4	250	2.1 MW	1	<10			MIL 217A FIG 7.5.13B	.165
R7	334711-41	FIXED FILM		470	2	1/4	250	2.1 MW	1	<10				.165
R8	334711-49	FIXED FILM		1K	2	1/4	250	—	.1	<10				.165

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC T/M SIGNAL COND CARD P/N 4216-67679 REV. C

CKT. SYM.	P/N	TYPE	MFR.	RATINGS VALUE MFD	TOL %	VOLTS	ADD'L. (SPECIFY)	OPERATING CONDITIONS VOLTS	% OPER. TO RATED VOLTS	ADD'L.	AMB. TEMP °C	REMARKS	FAILURE RATE SOURCE	UNITS
C401	337622-30	SOLID ELECTROL		2.2	10	20		6.43	32				MIL 217A FIG 7.6.364	.0017
C402	337622-30			2.2	10	20		6.43	32					.0017
C403	337622-30			2.2	10	20		4.45	22.2					.0011
C404	337622-30			2.2	10	20		4.7	23.5					.0012
C405	337622-30			2.2	10	20		6	30					.0015
C406	337622-22			22.0	10	15		11	74					.0200
C407	1784532-5	CERAMIC		100pf	10	200		.27 MV	410				MIL 217A FIG 6.298	.0050
C408	1784532-5	CERAMIC		100pf	10	200		6	410					.0050
C409	337633-12	MYLAR		0.1	10	50		6	12				MIL 217A FIG 7.6.338	.0010
C410	337622-30	SOLID ELECTROL		2.2	10	20		6.75	33.8				MIL 217A FIG 7.6.360	.0018
C411	337622-30			2.2	10	20		6.8	34					.0018
C412	337622-30			2.2	10	20		8.32	41.6					.0024

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ______ P/N ______ REV. ____ NOTES: ______

SCHEMATIC T/M SIGNAL COND CARD P/N 4216-67679 REV. C

CKT. SYM.	P/N	TYPE	MFR.	MAXIMUM RATINGS (PWR, VOLT, CURR) PARAMETER (SPECIFY)	VALUE	% DU CY	@ TA OR TC °C	OPERATING CONDITIONS P VALUE	% DU CY	TA OR TC RANGE °C	% OF RATED	REMARKS	FAILURE RATE SOURCE	UNITS
CR401	632281-1	SIL IN645		PW VR	600mW 225V		TA=25°C	—	50	45	<10	θ J-A = .33°C/mW	MIL 217A FIG 7.43B	.100
CR402								—			<10			.100
CR403								—	50		<10			.100
CR404								—	50		<10			.100
CR405	632281-1	SIL IN645		PW VR	600mW 225V			—			<10			.100
CR406	632638-109	SIL ZENER IN754A		PM VRZ	400mW 6.8V			6.8 mW			<10	θJA = .3125°C/mW		.300
CR407	632281-1	SIL IN645		PW VR	600mW 225V			.2 mW			<10	θJA = .33°C/mW		.100
CR408	632638-108	SIL ZENER IN754A		PM VRZ	400mW 6.8V			43.2 mW			10.8	θJA = .3125°C/mW		.300
Q401	336546	2N930 NPN SIL		PT	300mW			5 mW			<10	θJA = .5°C/mW	MIL 217A FIG 7.44B	.100
Q402	1602497-1		FAIRCHILD	P	200mW DISSIPATION			108 mW			54	MAXIMUM	MIL 217A FIG 7.14.2	0.4

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC T/M SIGNAL COND CARD P/N 4216-67679 REV. C

CKT SYM	P/N	TYPE	MFR.	RATINGS: VALUE OHMS	RATINGS: TOL %	RATINGS: POWER WATTS	RATINGS: VOLTS	OPERATING CONDITIONS: POWER WATTS	OPERATING CONDITIONS: VOLTS	OPERATING CONDITIONS: % OPER. TO RATED POWER	OPERATING CONDITIONS: AMB. TEMP °C	REMARKS	FAILURE RATE: SOURCE	FAILURE RATE: UNITS
R401	34711-25	FIXED FILM		100	2	1/4	250	—	—	—	45		MIL 217A FIG7.5.13B	—
R402	632375-525	METAL FILM		243K	1	1/8	250	6.7 MW	12.77	<10			MIL 217A FIG 7.5.9B	.15
R403	632375-496	METAL FILM		12.1K	1	1/8	250	3.44 MW	6.43	<10				.15
R404	334711-25	FIXED FILM		100	2	1/4	250	—	—	—			MIL 217A FIG7.5.13B	—
R405	632375-525	METAL FILM		243K	1	1/8	250	6.7 MW	12.77	<10			MIL 217A FIG7.5.9B	.15
R406	632375-496	METAL FILM		12.1K	1	1/8	250	3.44 MW	6.43	<10				.15
R407	334711-25	FIXED FILM		100	2	1/4	250	—	—	—			MIL 217A FIG7.5.13B	—
R408	334711-89	FIXED FILM		47K	2	1/4	250	8.5 MW	20	<10				.185
R409	1502078-06	VARIABLE WIREWOUND		10K	10	1	—	4 MW	2	<10			MIL 217A FIG7.5.4B	1.08
R410	334711-68	FIXED FILM		6.2K	2	1/4	250	2.27 MW	3.75	<10			MIL 217A FIG7.5.13B	.185
R411	334711-95	FIXED FILM		82K	2	1/4	250	4.17 MW	18.5	<10				.185
R412	334711-68	FIXED FILM		6.2K	2	1/4	250	2.55 MW	4	<10				.185
R413	334711-89	FIXED FILM		47K	2	1/4	250	12.9 MW	24.5	<10				.185
R414	334711-89	FIXED FILM		47K	2	1/4	250	.47 MW	4.7	<10				.185
R415	334711-83	FIXED FILM		27K	2	1/4	250	1.04 MW	5.3	<10				.185
R416	334711-89	FIXED FILM		47K	2	1/4	250	8.34 MW	19.8	<10				.185
R417	334711-25	FIXED FILM		100	2	1/4	250	—	—	—				—
R418	334711-25	FIXED FILM		100	2	1/4	250	—	—	—				—
R419	632375-456	METAL FILM		4.64K	1	1/8	250	5.4 MW	5	<10			MIL 217A FIG 7.5.9B	.15

RELIABILITY ANALYSIS WORK SHEET - RESISTORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC T/M SIGNAL COND CARD P/N 4216-67679 REV. C

				Ratings				Operating Conditions					Failure Rate	
Ckt Sym	P/N	Type	Mfr.	Value Ohms	Tol %	Power Watts	Volts	Power Watts	Volts	% Oper. to Rated Power	Amb. Temp °C	Remarks	Source	Units
R420	632375-472	METAL FILM		6.81K	1	1/8	250	7.18 MW	7	<10	45		MIL 217A FIG 7.5.98	.15
R421	632375-553	METAL FILM		47.5K	1	1/8	250	.84 MW	6.3	<10				.15
R422	334711-83	FIXED FILM		27K	2	1/4	250	—	.27 MW	<10			MIL 217A FIG 7.6.138	.185
R423	632375-632	METAL FILM		316K	1	1/8	250	—	4.5	<10			MIL 217A FIG 7.5.98	.15
R424	632375-528	METAL FILM		26.1K	1	1/8	250	23 MW	24.5	18.5				.159
R425	334711-85	FIXED FILM		33K	2	1/4	250	.53 MW	4.2	<10			MIL 217A FIG 7.5.138	.185
R426	334711-97	FIXED FILM		100K	2	1/4	250	1.64 MW	12.8	<10				.165
R427	334711-25	FIXED FILM		100	2	1/4	250	—	—	—				—
R428	632375-584	METAL FILM		100K	1	1/8	250	1.56 MW	12.5	<10			MIL 217A FIG 7.5.98	.15
R429	632375-538	METAL FILM		33.2K	1	1/8	250	16.6 MW	23.5	13.3				.153
R430	334711-25	FIXED FILM		100	2	1/4	250	—	—	—			MIL 217A FIG 7.5.138	—
R431	632375-553	METAL FILM		47.5K	1	1/8	250	2.78 MW	11.5	<10			MIL 217A FIG 7.5.98	.15
R432	632375-576	METAL FILM		82.5K	1	1/8	250	9.4 MW	27.75	<10				.15
R433	334711-25	FIXED FILM		100	2	1/4	250	—	—	—			MIL 217A FIG 7.5.138	—
R434	632375-520	METAL FILM		21.5K	1	1/8	250	3.22 MW	8.32	<10			MIL 217A FIG 7.5.98	.15
R435	334711-47	FIXED FILM		820	2	1/4	250	32.8 MW	5.2	13.1			MIL 217A FIG 7.5.138	.188
R436	632375-579	METAL FILM		88.7K	1	1/8	250	14.7 MW	36	12			MIL 217A FIG 7.5.98	.152
R437	334711-59	FIXED FILM		2.7K	2	1/4	250	—	—	—			MIL 217A FIG 7.5.138	—

RELIABILITY ANALYSIS WORK SHEET - CAPACITORS

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC RELAY CARD "A" P/N 4216-6768 REV. B

RELAY CARD "A" 4310-90848 —

				RATINGS				OPERATING CONDITIONS					FAILURE RATE	
CKT. SYM.	P/N	TYPE	MFR.	VALUE MFD	TOL %	VOLTS	ADD'L. (SPECIFY)	VOLTS	% OPER. TO RATED VOLTS	ADD'L.	AMB. TEMP °C	REMARKS	SOURCE	UNITS
C501	1784532-29	CERAMIC		.01	10	200		45.6	22.8		45		MIL 217A FIG 7.6.2A6	.0053

RELIABILITY ANALYSIS WORK SHEET - ELECTRON TUBES & SEMICONDUCTORS

ASSEMBLY ____________ P/N ____________ REV. ____ NOTES: ____________

SCHEMATIC Relay Card "A" P/N 4216-67680 REV. B

Relay Card "A" 4310-90848 —

Ckt. Sym.	P/N	Type	Mfr.	Maximum Ratings (Pwr, Volt, Curr) Parameter (Specify)	Value	% Du Cy	@ TA or TC °C	Operating Conditions P Value	% Du Cy	TA or TC Range °C	% of Rated	Remarks	Failure Rate Source	Units
CR501	632281-1	Si IN645		P_A V_R	600 mW 225 V		TA = 25°C	133 mW	50	45	11.1	θJ-A = 0.33°C/mW	MIL-217A Fig. 7.3.3D	.150
CR502								133 mW	50		11.1			.150
CR503								23 mW	50		410			.100
CR504								23 mW	50		410			.100
CR505								45 mW	50		410			.118
CR506								45 mW	50		410			.118
CR507								60 mW			40			.140
CR508								60 mW			40			.140
CR509								45 mW	50		40			.118
CR510								45 mW	50		40			.118

RELIABILITY ANALYSIS WORK SHEET - RELAYS* - SWITCHES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC RELAY CARD "A" P/N 4216-67650 REV. B

RELAY CARD "A" 4310-90848 —

CKT. SYM	P/N	TYPE	MFR.	RATINGS (CONTACTS) CURR.	OPEN VOLTAGE	LOAD	OPERATING CONDITIONS CURR.	OPEN VOLTAGE	LOAD	% OPER. TO RATED CURR.	ACTUAT. PER UNIT TIME	REMARKS	FAILURE RATE SOURCE	UNITS
K2	FLH (12 Volt Coil)	LATCHING MAGNETIC	POTTER + BRUMFIELD	5A	28	RES	.120 A			<10		COIL VOLTAGE = 22V AND COIL CURRENT = .09A	MIL 217A FIG 7.10.1	.151
K3 **	FCH (24 Volt Coil)	NON-LATCHING (SINGLE COIL)	POTTER + BRUMFIELD		28		.5A			10		COIL VOLTAGE = 24V COIL CURRENT = .27A		.151
K5 **	FLH (12 Volt Coil)	LATCHING MAGNETIC	POTTER + BRUMFIELD		28		.120 A			<10		COIL VOLTAGE = 22V COIL CURRENT = .09A		.151
K7	FLH (12 Volt Coil)	LATCHING MAGNETIC			28		2 MA			<10		COIL VOLTAGE = 22V COIL CURRENT = .09A		.151

** NOT USED ON RELAY CARD "A" (SCHEMATIC P/N 4310-90848)

*FOR RELAYS, COMPLETE THIS FORM FOR CONTACTS AND COMPLETE "INDUCTIVE DEVICES" FORM FOR COILS.

RELIABILITY ANALYSIS WORK SHEET - RELAYS* - SWITCHES

ASSEMBLY ______ P/N ______ REV. ______ NOTES: ______

SCHEMATIC RELAY CARD B P/N 4216-67681 REV. A

RELAY CARD B 4310-90841 —

CKT SYM	P/N	TYPE	MFR.	RATINGS (CONTACTS) CURR.	OPEN VOLTAGE	LOAD	OPERATING CONDITIONS CURR.	OPEN VOLTAGE	LOAD	% OPER. TO RATED CURR.	ACTUAT. PER UNIT TIME	REMARKS	FAILURE RATE SOURCE	UNITS
K1	FLH	LATCHING MAGNETIC	POTTER-BRUMFIELD	5A	28	RES	1A			20		COIL VOLTAGE = 22V COIL CURRENT = .094A	MIL 217A FIG 7.10.1	.151
K4	FCH	NON-LATCHING (SINGLE COIL)			28	RES	.3A			6		COIL VOLTAGE = 22V COIL CURRENT = .105A		.151
K6	FLH	LATCHING MAGNETIC			28	RES	1A			20		COIL VOLTAGE = 22V COIL CURRENT = .094A		.151
K8	FCH				28	RES	.3A			6		COIL VOLTAGE = 22V COIL CURRENT = .105A		.151
														.151

*FOR RELAYS, COMPLETE THIS FORM FOR CONTACTS AND COMPLETE "INDUCTIVE DEVICES" FORM FOR COILS.