IEEE Standard Specification Format Guide and Test Procedure for Single-Degree-of-Freedom Rate-Integrating Gyros

Sponsor
Gyro and Accelerometer Panel
of the
IEEE Aerospace Electronics System Society

Approved December 13, 1973
IEEE Standards Board

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Foreword

(This foreword is not a part of IEEE Std 517-1974, Specification Format Guide and Test Procedure for Single-Degree-of-Freedom Rate-Integrating Gyros.)

This standard was prepared by the Gyro and Accelerometer Panel of the Aerospace Electronics Systems Society of the Institute of Electrical and Electronics Engineers. It consists of two parts.

Part I is a specification format guide for the preparation of a rate-integrating gyro specification. It provides a common meeting ground of terminology and practice for manufacturers and users. The user is cautioned not to overspecify; only those parameters that are required to guarantee proper instrument performance in the specific application should be controlled. In general, the specification should contain only those requirements that can be verified by test or inspection. Parameters in addition to those given in this standard are not precluded. Figs 1 and 2 are to be used as a guide for the preparation of specific figures or drawings.

Part II is a compilation of recommended procedures for testing a rate-integrating gyro. These procedures, including test conditions to be considered, are derived from those currently in use. For a specific application, the test procedure should reflect the requirements of the specifications; therefore, not all tests outlined in this document need be included, nor are additional tests precluded. In some cases, alternative methods for measuring performance characteristics have been included or indicated.

The intent is for the specification writer to extract the applicable test conditions and equipment requirements from Section 9. for inclusion in the appropriate sections listed under Section 4.5. Similarly, it is intended that the writer extract the applicable test procedures from Section 10. for inclusion in the appropriate sections listed under Section 4.6. Part II can also be used as a guide in the preparation of a separate rate-integrating gyro test specification with appropriate section numbering.

Blank spaces in the text of this document permit the insertion of specific parameter values and their tolerances. Brackets are used to enclose alternative choices of dimensional units, signs, axes, etc. Boxed statements are included for information only and are not part of the specification or test procedures. The symbols used conform to IEEE Std 260-1967 , Letter Symbols for Units Used in Electrical Science and Electrical Engineering. Terminology used conforms to Aerospace Industries Association EETC Report 5 (Revision A), Standard Gyro Terminology.

This document defines the requirements and test procedures for a conventional single-degree-of-freedom rate-integrating gyro in terms of characteristics unique to the gyro. The requirements contained herein are intended to cover applications in which the dynamic angular inputs to which the gyro is subjected are benign relative to the accuracy required. This will cover most gimballed platform applications and those nongimballed applications (for example, space vehicle attitude control systems) in which the dynamic inputs are not so severe as to make additional parameters significant. The rate-integrating gyro provides a voltage output proportional to angular displacement of the case about the input axis when in an open-loop mode or when captured by a servoed platform, or a current proportional to angular rate about the input axis when captured through an external loop using the gyro torquer. A model equation is given in Section 6.3 for reference, to be included in a specification only to the extent necessary.

Appendix A lists various rate-integrating gyro design features for which this format is applicable. The table is not intended to make any suggestion regarding the selection of particular design features that might restrict the free choice of manufacturers.

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The IEEE will maintain this document current with the state of the technology. Comments are invited on this document as are suggestions for additional material. These should be addressed to:

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New York, N.Y. 10017

This publication represents a group effort on a large scale. A total of 167 individuals attended 37 meetings of the Gyro and Accelerometer Panel while work on this standard was in progress. The following members were responsible for this work:

R. B. Clark *(Chairman, 1967)*
C. O. Swanson *(Chairman, 1968)*
H. A. Dinter *(Chairman, 1969)*
N. F. Sinnott *(Chairman, 1970)*
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K. W. Homb *(Chairman, 1972)*
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In addition to the above working group, the following members of the Gyro and Accelerometer Panel also approved this standard by letter ballot.

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IEEE Standard Specification Format Guide and Test Procedure for Single-Degree-of-Freedom Rate-Integrating Gyros

Part I—Specification Format

1. Scope

This specification defines the requirements for a single-degree-of-freedom rate-integrating gyro to be used as a sensor in [an attitude control system, a gimbal platform, an angular displacement measuring system, an angular rate measuring system, _____.] The external electronics or control system are not considered to be part of the gyro.

2. Applicable Documents

The following documents form a part of the specification to the extent specified herein. In the event of any conflict between the requirements of this document and the listed documents, the requirements of this document shall govern.

Give identification number, title, date of issue, and revision letter of each listed document.

2.1 Specifications

2.1.1 *Government*

2.1.2 *Industry/Technical*

2.1.3 *Company*

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2.2 Standards

2.2.1 *Government*

2.2.2 *Industry/Technical*

1) Aerospace Industries Association, EETC Report 5 (Revision A), Standard Gyro Terminology, June 1965[1]
2) IEEE Std 260-1967 , Letter Symbols for Units Used in Electrical Science and Electrical Engineering

2.2.3 *Company*

2.3 Drawings

2.3.1 *Government*

2.3.2 *Industry/Technical*

2.3.3 *Company*

2.4 Bulletins

2.4.1 *Government*

2.4.2 *Industry/Technical*

2.4.3 *Company*

2.5 Other Publications

Other applicable documents should be listed under the appropriate categories.

3. Requirements

3.1 Description

The major components of the rate-integrating gyro herein specified are: a rotor driven by a _____ spin motor, _____ damping, a _____ pickoff, a _____ torquer, and _____ gimbal suspension.

To fill in the blanks, refer to Appendix A.

3.2 General Requirements

3.2.1 *Precedence*

In the event of conflict among the purchase agreement, this specification, and other documents referred to herein, the order of precedence shall be as follows:

[1] Available from: National Standards Association, Inc 1321 Fourteenth Street, NW Washington, DC 20005

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1) Purchase agreement
2) This specification and its applicable drawings (see Sections 3.4.2 and 3.5.1)
3) Other applicable documents (see Section 2)

3.2.2 *Definitions*

The following document and the model equation of Section 6.3 define terminology used in this specification: Aerospace Industries Association, EETC Report 5 (Revision A), Standard Gyro Terminology, June 1965

3.3 Performance

Performance characteristics shall be as specified hereinafter. The tolerances include a summation of manufacturing and test errors and environmental effects. Any exception due to environmental effects will be listed in Section 3.6.3.1.

> When required by the application, the sensitivity of a gyro parameter to variations in voltage, frequency, temperature, or other variables shall be included in the paragraph specifying that parameter.

3.3.1 *Input Angles*

3.3.1.1 *Input Limits*

The minimum angular input limits about the gyro input axis shall be ± _____ [rad, °].

> The positive and negative input limits need not be equal.

3.3.1.2 *Limit Stops*

The output angle shall be mechanically limited, corresponding to an input angle of ± _____ [rad, °].

> The positive and negative limit stops need not be equal and are sometimes specified in terms of pickoff output voltage.

3.3.2 *Gyro Scale Factor*

_____ ± _____ V/[rad, °] input angle.

3.3.3 *Gyro Gain*

H/C, _____ ± _____ [rad/rad, ° /°].

3.3.4 *Characteristic Time*

J/C, _____ ± _____ seconds.

3.3.5 *Operating Temperature*

_____ ± _____ [K, °C].

> Operating temperature is defined as the temperature at one or more gyro elements when the gyro is in the specified operating environment. These elements may include the spin motor winding, the flange, the pickoff, the torquer, the temperature sensor, etc. In this thermal environment, all operating specifications must be met.

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3.3.6 *Run-Up Time*

_____ seconds maximum to _____ percent of [full speed, synchronous speed].

3.3.7 *Run-Down Time*

_____ seconds minimum from _____ percent of [full speed, synchronous speed] to _____ percent of [full speed, synchronous speed].

3.3.8 *Warm-Up Time*

_____ [second, minute] maximum.

3.3.9 *Torquer Performance*

3.3.9.1 *Command Rate Scale Factor*

_____ ± _____ [(rad/s)/mA, (rad/h)/mA, (° /s)/mA, (° /h)/mA].

For a variable reluctance torquer the scale factor shall be _____ ± _____ [(rad/s)/mA^2, (rad/h)/mA^2, (° /s)/mA^2, (° /h)/mA^2].

Sometimes nonlinear torquers are specified, in which case a table defining rate versus input should be supplied.

3.3.9.2 *Command Rate Scale Factor Composite Error*

_____ percent output range, maximum.

Specific terms comprising composite error may be specified in addition to, or instead of, composite error.

3.3.9.3 *Continuous Command Rate*

Minimum: _____ [rad/s, rad/h, ° /s, ° /h].

3.3.9.4 *Maximum Command Rate*

Minimum: _____ [rad/s, rad/h, ° /s, ° /h] for a minimum of _____ seconds.

The degree to which performance may be degraded during application of maximum command rate, and the recovery time, may both be specified if applicable.

3.3.10 *Rotor Rotation Detectors*

For pulse output type, specify peak output, repetition rate, pulse width, and rise time or fall time, or both. For near sinusoidal type, specify total output, fundamental signal, and fundamental frequency. Other types of RRD (rotor rotation detectors) should be specified in accordance with their characteristics.

3.3.10.1 *Peak Output*

_____ ± _____ V (at rated speed).

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3.3.10.2 *Repetition Rate*

_____ times rotor speed.

3.3.10.3 *Pulse Width*

_____ seconds at _____ V (at rated speed).

3.3.10.4 [*Rise, Fall*] *Time*

_____ ± _____ μs from _____ percent to _____ percent peak amplitude.

3.3.10.5 *Total Output*

_____ ± _____ V rms (at rated speed).

3.3.10.6 *Fundamental Signal*

(Sinusoidal) _____ percent of total output.

3.3.10.7 *Fundamental Frequency*

_____ times rotor speed.

3.3.11 *Pickoff*

3.3.11.1 *Pickoff Scale Factor*

_____ ± _____ V/[rad, °] output angle.

3.3.11.2 *Pickoff Composite Error*

_____ percent output range, maximum.

> Specific terms comprising composite error may be specified in addition to, or instead of, composite error.

3.3.11.3 *Pickoff Electrical Null*

1) _____ mV [rms, peak to peak] total, maximum
2) _____ mV [rms, peak to peak] quadrature, maximum
3) _____ mV [rms, peak to peak] in phase, maximum

> For ac pickoffs the electrical null is composed primarily of harmonics, noise, and quadrature (voltage at a fundamental frequency but 90° out of phase with the signal output for large signals). A common practice is to achieve a minimum in-phase voltage after which the quadrature and total voltage are determined.

3.3.12 *Elastic Restraint Drift Rate Coefficient*

K/H _____ [(rad/h)/rad, (° /h)/°] maximum.

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3.3.13 *Gimbal Retardation (Gimbal Friction)*

Peak gimbal retardation _____ ° /h maximum at a [gimbal, case] rotation rate of _____ ° /h. Sustained gimbal retardation _____ [rad/h, ° /h] for [rad/h, ° /h] [gimbal, case] rotation. There shall be no more than _____ deviations greater than _____ [rad/h, ° /h].

Gimbal retardation may also be specified with the gyro above and below operating temperature.

3.3.14 *Acceleration-Insensitive Drift Rate*

3.3.14.1 *Drift Rate*

D_F, 0 ± _____ [rad/h, ° /h.

3.3.14.2 *Repeatability*

_____ [rad/h, ° /h] [maximum spread, 1_σ, _____].

Repeatability involves changes in drift rates that occur between periods of operation. Motor shut downs, cool downs, time between runs, and other factors pertinent to the particular application shall be specified.

3.3.15 *Acceleration-Sensitive Drift Rate Coefficient*

3.3.15.1 *Drift Rate Coefficient*

1) D_I, 0 ± _____ [(rad/h)/*g*, (° /h)/*g*]
2) D_S, 0 ± _____ [(rad/h)/*g*, (° /h)/*g*]
3) D_O, 0 ± _____ [(rad/h)/*g*, (° /h)/*g*]

3.3.15.2 *Repeatability*

1) D_I, _____ [(rad/h)/*g*, (° /h)/*g*][maximum spread, 1 σ, _____]
2) D_S, _____ [(rad/h)/*g*, (° /h)/*g*][maximum spread, 1 σ, _____]
3) D_O, _____ [(rad/h)/*g*, (° /h)/*g*][maximum spread, 1 σ, _____]

Repeatability involves changes in drift rates that occur between periods of operation. Motor shut downs, cool down, time between runs, and other factors pertinent to the particular application shall be specified.

3.3.16 *Acceleration-Squared-Sensitive Drift Rate Coefficient*

0 ± _____ [(rad/h)/g^2, (° /h)/g^2].

The specification should state whether this requirement applies to each of the coefficients D_{IO}, D_{II}, D_{SS}, D_{OS}, and D_{IS} individually, or represents a maximum value for acceleration along any axis. The coefficient(s) should be specified as a function of frequency if applicable.

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3.3.17 *Random Drift Rate*

_____ [rad/h, ° /h] (1σ), with the gyro oriented [OA (output axis) vertical, IA (input axis) vertical, OA polar, _____].

> Requirements for more than one orientation may be specified. Test duration and either sample time or frequency band should be specified, dependent upon data reduction technique.

3.3.18 *Output Noise*

_____ [rad/h, rad/s, rad, ° /h, ° /s, °] [rms, peak to peak] maximum at frequencies _____ Hz to _____ Hz.

> Sometimes referred to as "signal modulation," output noise is usually specified at pickoff in-phase null. Other output angles may be specified.

3.3.19 *Dynamic Response*

> Frequency response testing is generally specified for low- and medium-gain gyros. The response of high-gain gyros may be more meaningfully controlled by specifying the step response.

3.3.19.1 *Frequency Response*

_____ [dB, percent)] maximum deviation and _____ [rad, °] maximum phase deviation from the ideal response of an overdamped spring-mass inertia system with the nominal parameters defined in Sections 3.3.2, 3.3.3, and 3.3.4 from _____ Hz to _____ Hz at an [applied, command] input rate amplitude of _____ ° /s.

3.3.19.2 *Settling Time*

The time for the gyro output to return to within [rad/ h, ° /h] of its final value after being angularly disturbed.

1) _____ [rad, °] about the ORA (output reference axis) shall be _____ seconds maximum
2) _____ [rad, °] about the IRA (input reference axis) shall be _____ seconds maximum
3) _____ [rad, °] about the SRA (spin reference axis shall be _____ seconds maximum

> Settling time for other than angular disturbances may also be specified.

3.3.20 *Axis Alignment*

With the pickoff at null, the projection of the IA on the IRA- SRA plane shall be aligned to the IRA within _____ [mrad, _____]. The IA shall be parallel to the IRA- SRA plane within _____ [mrad, _____].

> The OA perpendicularity to the IRA-SRA plane, SA perpendicularity to the OA, and alignment stability may also be specified.

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3.3.21 *Angular Acceleration Sensitivity About the Output Axis*

_____ [(rad/h)/(rad/s^2), (° /h)/(rad/s^2)] maximum.

> The angular acceleration sensitivity about the output axis is nominally equal to gimbal moment of inertia divided by rotor angular momentum. For certain gyro configurations, other effects should be considered such as the inertia of transported fluid, misalignment instabilities, frictional effects, etc.

3.3.22 *Reference Constants*

These constants are for reference only. They are not specified independently, because they may vary within the framework of the specification, or because they are difficult or impossible to measure independently in a complete gyro. Nominal values are listed.

3.3.22.1 *Rotor Angular Momentum*

_____ g·cm^2/s.

3.3.22.2 *Rotor Speed*

_____ r/min.

3.3.22.3 *Gimbal Moment of Inertia*

_____ g·cm^2.

> For certain gyro configurations, the effective gimbal moment of inertia that includes the effect of transported fluid should be stated.

3.3.22.4 *Damping Coefficient*

C, _____ [(N·m)/(rad/s), (dyn·cm)/(rad/s)].

3.3.23 *Polarity*

Shall conform to [drawing number _____, Fig 1], [drawing number _____, Fig 2].

3.3.23.1 *Pickoff*

The voltage from the pickoff secondary line to return shall be [in, out of] phase, within the pickoff carrier phase shift, with the voltage from the pickoff primary line to return for positive angular displacement about the IA.

> For dc pickoffs this shall read: The voltage (or resistance) from the pickoff output line to the pickoff excitation line shall [increase, decrease] for positive angular displacement about the IA. The preferred convention for pickoff output polarity is “in-phase” or “increase” for positive angular displacements about the IA.

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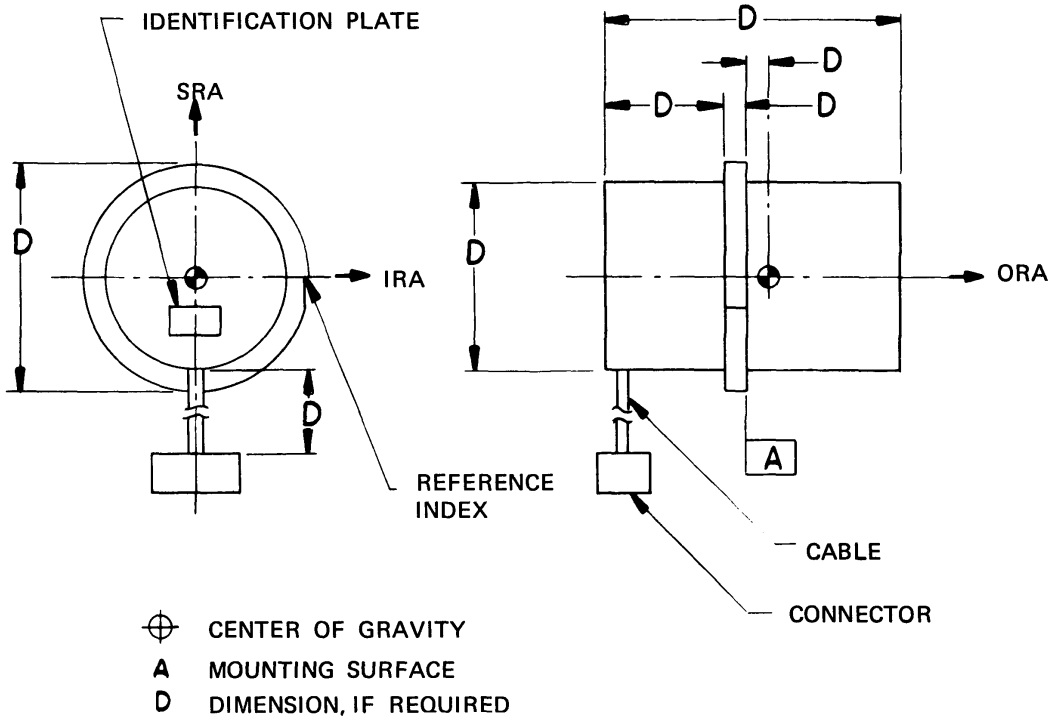


Figure 1—Typical Rate-Integrating Gyro Outline Drawing

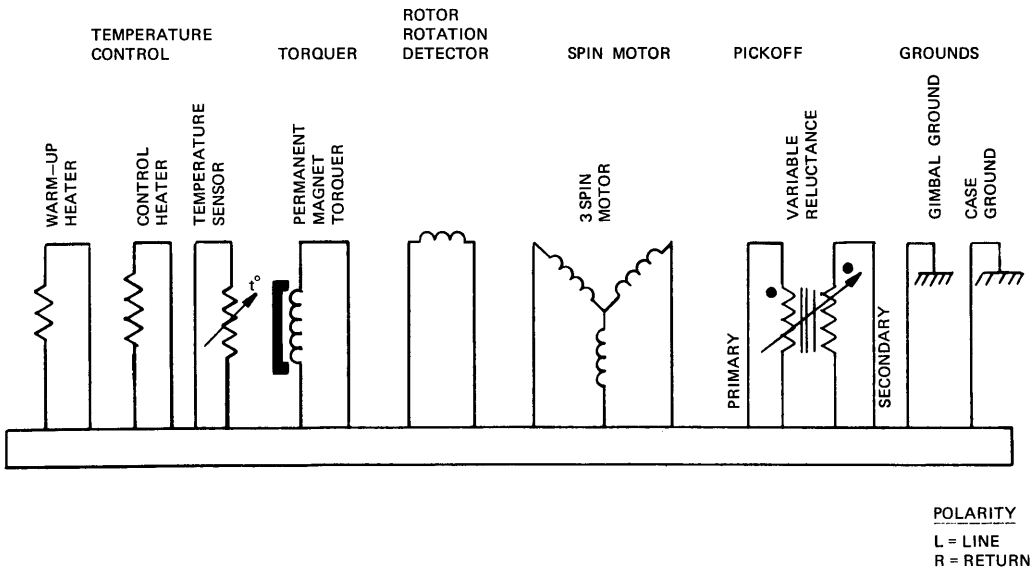


Figure 2—Typical Rate-Integrating Gyro Electrical Schematic
(Note: Terminal or lead designation should be shown.)

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3.3.23.2 *Motor*

The rotor shall rotate in the direction indicated by the SRA for [ac excitation phase sequence phase _____ leads phase _____ leads phase _____; dc positive voltage, spin motor line to return].

3.3.23.3 *Torquer*

An increasing in-phase pickoff output shall result when the voltage from the torquer control line to return is [positive, negative].

> For a variable reluctance torquer this shall read: An increasing in-phase pickoff output shall result when the voltage from the control line to return has the [same, opposite] [polarity, phase] as the voltage from the excitation line to return. The preferred convention for torquer polarity is “positive” or “same.”

3.4 Mechanical Requirements

Mechanical characteristics shall be as specified hereinafter.

3.4.1 *Exterior Surfaces*

All exterior surfaces must withstand the environment herein specified and the handling expected in the normal course of operation, testing, and maintenance without deterioration that causes nonconformance to this specification.

> Additional requirements controlling surface finish, workmanship, processing, etc, may be designated by the procuring agency.

3.4.2 *Outline and Mounting Dimensions*

Shall conform to [drawing number _____, Fig 1].

3.4.3 *Gyro Axes*

The IRA and the SRA are determined from the axis alignment provisions on the gyro case.

3.4.4 *Weight*

_____ ± _____ [g, kg, oz, lb].

> When accessories such as cable, connector, or preamplifier are to be included in the weight, the specifications shall so state.

3.4.5 *Seal*

The gyro shall be sealed such that no fluid leakage is detected under _____ power magnification after being subjected to an external vacuum at _____ ± _____ torr and a gyro temperature of _____ ± _____ °C for a minimum of _____ minutes.

> In some cases, other procedures may be more appropriate, such as the use of fluorescent tracers in the fluid to facilitate leak detection, or weight loss may be measured to indicate leakage. For gas-filled gyros, specify allowable leakage rate.

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3.4.6 *Rotor Suspension*

The suspension of the rotor shall be of the _____ type.

3.4.7 *Gimbal Suspension*

The suspension of the gimbal (float) shall be of the _____ type.

3.4.8 *Identification of Product*

The gyro shall be identified on the surface and in the manner indicated in [drawing number _____, Fig 1]. Identification shall include:

1) Rate-integrating gyro
2) Specification number
3) Unit serial number
4) Axis identification marking as shown in [drawing number _____, Fig 1]
5) Manufacturer's name or symbol

The purchase agreement may require additional identification such as date of manufacture.

3.5 Electrical Requirements

Electrical characteristics shall be as specified hereinafter.

Transient conditions of electrical excitation may need to be specified.

3.5.1 *Schematic*

The electrical circuits shall be connected as shown in [drawing number _____, Fig 2].

3.5.2 *Circuit Excitations and Impedances*

The circuit excitations and impedances shall be as specified hereinafter.

3.5.2.1 *Spin Motor*

1) Excitation, line to line: _____ ± _____ V [dc, ac, _____ phase, _____ ± _____ Hz]

Specify wave shape if other than sinusoidal, also grounding, harmonic content, ripple, power supply impedance, etc, if required.

2) Starting current: _____ mA maximum
3) Starting power: _____W maximum
4) Running current: _____ mA maximum
5) Running power: _____W maximum

As an alternate to running current, and running power, running voltamperes may be specified, or the specification may state: The impedance of the spin motor winding shall be _____ ± _____ Ω [+, −]*j* _____ ± _____ Ω when measured at _____ Hz and at [operating temperature, _____ ± _____ ° C].

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6) Phase splitting capacitor: _____ ± _____ μF
7) Overvoltage: _____ percent for _____ seconds maximum

3.5.2.2 *Pickoff*

1) Excitation: _____ ± _____ [V, mA] [dc, ac, _____ Hz ± _____ Hz, phase locked with spin motor excitation]
2) Harmonics: _____ percent maximum of fundamental

Specify wave shape if other than sinusoidal.

3) Primary impedance: The impedance of the primary as measured with the secondary [open circuited, connected to the load impedance specified in (5) below] shall be _____ ± _____ Ω [+, −]*j* _____ ± _____ Ω when measured at _____ Hz and at [operating temperature, _____ ± _____ °C]
4) Secondary impedance: The impedance of the secondary as measured with the primary [open circuited, short circuited] shall be _____ ± _____ Ω [+, −]*j* _____ ± _____ Ω, when measured at _____ Hz and at [operating temperature, _____ ± _____ °C]
5) Load impedance: _____ ± _____ Ω[+, −] *j* _____ ± _____ Ω
6) Carrier phase shift, primary to secondary voltage: _____ ± _____ °, when connected to the specified load

3.5.2.3 *Temperature Control*

The resistance of the temperature sensor(s) shall be _____ ± _____ in the operating temperature range specified in Section 3.3.5. The temperature rise of the sensor due to self-heating shall not exceed _____ [K, °C] at _____ mA. The resistance scale factor of the temperature sensor(s) shall be [+, −] _____ ± _____ Ω/°C, at operating temperature.

1) Warm-up heater excitation: _____ ± _____ V [dc, ac, _____ ± _____ Hz]
2) Warm-up heater power: _____W maximum
3) Control heater excitation: _____ ± _____ V [dc, ac, _____ ± _____ Hz]
4) Control heater power: _____W maximum

Thermistor, thermocouples, thermostats, or other means of temperature control may be specified.

3.5.2.4 *Torquer*

Torquer winding impedance: _____ ± _____ Ω + *j* _____ ± _____ Ω at _____ Hz at [operating temperature, _____ ± _____ °C].

For variable reluctance torquer, specify excitation winding current or voltage, and impedances of both windings.

3.5.2.5 *Rotor Rotation Detector*

1) Impedance: _____ Ω, maximum, when measured at _____ Hz
2) Load: _____ Ω, minimum

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3.5.2.6 *Gimbal Suspension*

For floated-electrostatic or magnetic centering suspensions, and for hydrostatic fluid-bearing suspensions, with an internal pump, the following parameters should be specified.

1) Excitation, line to line: _____ ± _____ V [dc, ac, _____ ± _____ Hz]
2) Current: _____ ± _____ mA
3) Input impedance: _____ ± _____ Ω[+, −]*j* _____ ± _____ Ω when measured at Hz _____ and at [operating temperature, _____ ± _____ °C]

3.5.3 *Insulation Resistance*

The insulation resistance between isolated electrical circuits and between the gyro case and circuits isolated from the gyro case shall not be less than _____ MΩ measured at _____ ± _____ V dc applied for _____ ± _____ seconds.

3.5.4 *Dielectric Strength*

The leakage current shall not exceed _____ μA when _____ ± _____ V rms, _____ Hz are applied between isolated electrical circuits and between the gyro case and electrical circuits isolated from the gyro case for _____ ± _____ seconds.

3.5.5 *Electromagnetic Interference*

Electromagnetic interference shall conform with _____.

In the United States, a common standard is MIL-STD-461.

3.5.6 *Maximum Magnetic Leakage Measurement*

_____ [mT, G] measured at a distance of _____ ± _____ [cm, in] along the _____ [axis, axes].

3.6 Environmental Requirements

This section contains environmental requirements only. Test procedures that are to be used, including required combinations of environments, are covered in Section 4.6.

3.6.1 *Storage*

The gyro shall conform to all requirements of this specification after exposure to the following environments or specified combinations thereof, while packaged as specified in Section 5.

The procuring organization shall list the applicable environments from Section 3.6.4 and specify the limits for each based on the storage conditions expected.

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3.6.2 *Transport*

The gyro shall conform to all requirements of this specification after exposure to the following environments or specified combinations thereof, while packaged as specified in Section 5.

> The procuring organization shall list the applicable environments from Section 3.6.4 and specify the limits for each based on the transportation conditions expected.

3.6.3 *Operation*

> In order to properly specify the environmental requirements for a gyro, three different sets of environments and/or environmental limits as defined in Sections 3.6.3.1, 3.6.3.2, and 3.6.3.3 may need to be described. A guide for the selection of the environments most often included in each of the three sets can be obtained by referring to Table 3 of this document.

3.6.3.1 *Operating Environment*

The gyro shall conform to all requirements of this specification during exposure to the following environments or specified combinations thereof (except during exposure to _____ where the deviations of this specification are given in the following sections).

> Where degraded performance is to be allowed, include the parenthetical phrase in Section 3.6.3.1 and list in the blank space those environments for which degraded performance is allowed. The procuring organization should list the applicable environments from Section 3.6.4 and specify the limits for each based on the conditions expected when the gyro is in use. For those environments where degraded performance is allowed, specify the performance deviation in the section that specifies the environment.

3.6.3.2 *Survival Environment, Operating*

The gyro shall conform to all requirements of this specification after the operating gyro has been exposed to the following environments or specified combinations thereof.

> The procuring organization shall list the applicable environments from Section 3.6.4 and specify the limits for each based on the conditions expected when the gyro is operating but not in use.

3.6.3.3 *Survival Environment, Nonoperating*

The gyro shall conform to all requirements of this specification after the nonoperating gyro has been exposed to the following environments or specified combinations thereof.

> The procuring organization shall list the applicable environments from Section 3.6.4 and specify the limits for each based on the conditions expected when the gyro is not operating. Such conditions are expected to occur when the gyro is mounted in the system and the system is stored or transported in severe environments.

3.6.4 *Environments*

Environmental characteristics shall be as specified hereinafter.

> This list is intended as an aid to the selection of the applicable environments under Sections 3.6.1, 3.6.2, and 3.6.3. A Section 3.6.4 in this form would not be included in a final specification.

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3.6.4.1 *Vibration*

Sinusoidal: _____ in DA (double amplitude) _____ to _____ Hz; _____ [m/s^2, *g*] peak, _____ to _____ Hz. Sweep rate: _____ minutes per octave (continuous). Exposure time: _____ per axis.

> Axes shall be defined.
>
> When available, supply the specific vibration characteristics including dwell frequencies, frequency spectrum, time duration, etc.
>
> If exposure to random vibration is required, power spectral density, bandwidth, peak acceleration level, and duration shall be specified.

3.6.4.2 *Mechanical Shock*

_____ [m/s^2, *g*] peak, _____ wave shape, _____ ms, _____ shock(s) per axis.

> Gyro axes and direction of shock shall be defined. A figure may be included to describe more complex waveforms. A shock spectrum may be specified.

3.6.4.3 *Linear Acceleration*

_____ [m/s^2, *g*], exposure time _____.

> Gyro axes and direction of acceleration shall be defined.

3.6.4.4 *Mechanical Overload*

The gyro shall perform within specification after positive and negative angular rates of _____ [rad/s, ° /s] have been applied about the _____ [axis, axes] for _____ seconds a total of _____ times per direction.

The gyro shall perform within specification after positive and negative angular accelerations of _____ [rad/s^2, ° $/s^2$] have been applied about the _____ [axis, axes] for _____ seconds a total of _____ times per direction.

3.6.4.5 *Temperature*

_____ °C to _____ °C.

3.6.4.6 *Thermal Shock*

_____ °C to _____ °C within _____ seconds.

> If exposure to cyclic conditions is required, temperature limits for each level, dwell times, and sequence shall be specified. A figure may be included to describe more complex profiles.

3.6.4.7 *Thermal Radiation*

W/cm^2 of radiation of wavelength from _____ to _____ meters; exposure time: _____.

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3.6.4.8 *Ambient Air Pressure*

_____ [Pa,[2] torr, inHg, lb_f/in^2] to _____ [Pa, torr, inHg, lb_f/in^2].

3.6.4.9 *Acoustical Noise*

_____ dB referenced to 2×10^{-5} Pa, _____ to _____ Hz; exposure time: _____.

> When available, supply the specific decibel versus frequency for the application. Sweep rate may be specified as _____ minutes per octave (continuous), if applying sinusoidal acoustic noise.

3.6.4.10 *Humidity*

_____ percent relative humidity for, _____ hours obtained from steam or distilled water having a pH value of _____ ± _____.

3.6.4.11 *Air Currents*

_____ [m/s, ft/s].

> Gyro axes and direction of air flow shall be defined.

3.6.4.12 *Fungus*

> Specify fungi organisms, length of exposure, and temperature and humidity conditions during exposure.

3.6.4.13 *Salt Spray*

_____ percent salt solution; exposure time: _____

3.6.4.14 *Nuclear Radiation*

_____ [J/kg, rad] with an exposure of _____ [(J/kg)/s, rad/s] and/or combinations of _____ particles at a fluence of _____ $/cm^2$ with energy greater than _____ MeV.

3.6.4.15 *Magnetic Fields*

_____ [mT, G]; exposure time: _____

> Gyro axes and direction of field shall be defined. If exposure to varying fields is required, the nature of the variation shall be described. Demagnetization may be necessary following exposure.

3.6.4.16 *Electromagnetic Fields*

Electromagnetic fields shall conform with _____

> In the United States, a common standard is MIL-STD-461.

[2] The term “pascal” and the symbol “Pa” have been adopted for the unit of pressure previously referred to as the “newton per square meter.” Use of this term has been approved by the IEEE, IEC, ISO, and Conference Generale des Poids et Mesures.

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3.6.4.17 *Sand and Dust*

_____ [g/m^3, g/ft^3] at a velocity of _____ ± _____ [m/s, ft/min]; exposure time: _____. Relative humidity not to exceed _____ percent.

Specify particle size, shape, and chemical composition.

3.6.4.18 *Sunshine*

_____ ± _____ [W/m^2, w/ft^2] of wavelength _____ to _____ meters; exposure time: _____

Describe distribution of power density versus wavelength.

3.6.4.19 *Rain*

_____ ± _____ [mm/h, in/h] consisting of droplets having a minimum diameter of _____ mm; exposure time: _____

3.6.4.20 *Excitation Voltage and Frequency Variation*

The excitation voltage and frequency required shall conform with _____

In the United States, a common standard is MIL-STD-704.

3.6.4.21 *Life*

3.6.4.21.1 *Storage*

_____ [months, years].

3.6.4.21.2 *Operating*

_____ hours.

3.6.4.21.3 *Start Cycles*

_____ minimum.

Life may need to be specified under other conditions.

3.7 Reliability

3.7.1 *Reliability Program*

The reliability program required shall conform with _____

In the United States, a common standard is MIL-STD-785.

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3.7.2 *MTBF (Mean Time Between Failure)*

The MTBF lower _____ percent confidence limit shall be a minimum of _____ hours.

4. Quality Assurance Provisions

4.1 Classification of Tests

Inspection and testing shall be classified as follows:

1) *Acceptance Tests*. Acceptance tests are those tests accomplished on gyros submitted for acceptance under contract
2) *Qualification Tests*. Qualification tests are those tests accomplished on gyros submitted for qualification as a satisfactory product
3) *Reliability Tests*. Reliability tests are those tests performed to demonstrate the reliability specified in Section 3.7

4.2 Acceptance Tests

Acceptance tests shall consist of the following:

1) Individual tests
2) Sampling tests

4.2.1 *Individual Tests*

Each gyro shall be subjected to the following tests described under Section 4.6.

The list of individual tests shall be specified by the procuring organization based on individual requirements. Those tests that are usually specified as individual tests are listed below. A run-in period under specified conditions may be required before beginning individual tests.

1) Section 4.6.1, Examination of Product (Mechanical)
2) Section 4.6.2, Examination of Product (Electrical)
3) Section 4.6.3, Leak Test
4) Section 4.6.4, Polarity
5) Section 4.6.5.3, Operating Temperature
6) Section 4.6.6.3, Electrical Null
7) Section 4.6.7.1, Command Rate Scale Factor
8) Section 4.6.8, Rotor Rotation Detector
9) Section 4.6.9, Spin Motor Test Series
10) Section 4.6.10, Axis Alignment (input axis misalignment only)
11) Section 4.6.11.2, Limit Stops
12) Section 4.6.12.1, Gyro Scale Factor
13) Section 4.6.13.1, Acceleration-Insensitive Drift Rate
14) Section 4.6.13.2, Acceleration-Sensitive Drift Rate Coefficient
15) Section 4.6.13.4, Elastic Restraint Drift Rate Coefficient
16) Section 4.6.13.5, Gimbal Retardation (Gimbal Friction)
17) Section 4.6.13.6, Random Drift Rate

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18) Section 4.6.14, Output Noise

There are other individual tests that are not generally specified but that may be included under individual tests based on specific application. In some cases the gyros are subjected to specific environmental tests.

4.2.2 *Sampling Plans and Tests*

4.2.2.1 *Sampling Plans*

This section is intended to designate a sampling plan if required. Sampling plans are up to the discretion of the procuring organization based upon usage, size of contract, individual requirements, etc.

Gyros selected in accordance with specification _____ shall be subject to the tests specified in Section 4.2.2.2 as described in Section 4.6.

In the United States, selection according to MIL-STD-105 is common.

4.2.2.2 *Sample Tests*

In addition to the individual tests listed in Section 4.2.1, the procuring organization shall specify from Section 4.6 those tests that shall be performed on gyros selected by Section 4.2.2.1. Sampling plan units may be used for delivery unless the procuring agency specifies life tests or other destructive type tests under the sampling plan.

4.2.2.3 *Rejection and Retest*

When one item selected from a production run fails to meet the specification, the procuring organization shall be immediately notified of the failure, and at the discretion of the procuring organization no items still on hand or later produced shall be accepted until the extent and cause of failure are determined. After corrections have been made, all necessary tests shall be repeated. For operational and production reasons, individual tests may be continued pending the investigation of a sampling plan failure.

Other requirements suitable to an individual contract may be substituted for this section.

4.2.2.4 *Defects in Items Already Accepted*

The investigation of a test failure could indicate that defects may exist in items already accepted. If so, the manufacturer shall fully advise the procuring organization of defects likely to be found and of methods for correcting them.

4.3 Qualification Tests

4.3.1 *Qualification Test Samples*

A sample of _____ gyros manufactured in accordance with the requirements of this specification shall be subjected to qualification tests specified herein at an activity designated by the procuring organization.

If the product is later modified in any way, the modified form shall be subjected to and pass those qualification tests designated by the procuring organization.

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The qualification test samples shall be identified with the manufacturer's own part number and any other information required by the procuring organization.

4.3.2 *Qualification Tests*

The procuring organization will specify from Section 4.6 those tests, or combination of tests, that shall be performed on gyros submitted for qualification.

4.4 Reliability Tests

The reliability tests may be performed at the gyro or the subassembly level, or both.

4.4.1 *Run In*

Each gyro shall be subjected to a run-in period of _____ hours under the following conditions.

Specify environment and operating conditions. Consideration shall be given to not compromising the useful operating life by excessive test time during run in.

4.4.2 *Demonstration Testing*

The MTBF requirements of Section 3.7.2 shall be demonstrated by testing _____ units for _____ hours each, and a minimum of _____ hours combined.

Stress level test shall conform with _____

In the United States, testing in accordance with MIL-STD-781 is common. Other methods of demonstration testing may be selected at the discretion of the procuring organization. A demonstration test plan shall be prepared to define test conditions, failures, types of tests, etc.

4.5 Test Conditions and Equipment

The procuring organization shall specify from Part II, Section 9, the nominal test conditions and test equipment required. The conditions shall apply to all tests less otherwise specified. When a test condition is specified, the complete test condition shall be detailed in this specification. The test equipment required shall also be listed by name and model, part number, or performance requirement.

4.6 Test Methods

Instructions for performing specified tests in this section are detailed in Part II, Section 10. When a test is specified, the complete test method shall be detailed in this specification, including requirements to be met to determine satisfactory performance. A test method should not be listed in Section 4.6 unless a requirement exists in Section 3. of this specification.

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4.6.1 ***Examination of Product (Mechanical)***

4.6.2 ***Examination of Product (Electrical)***

4.6.2.1 ***Impedance***

4.6.2.2 ***Dielectric***

4.6.2.3 ***Insulation Resistance***

4.6.3 ***Leak Test***

4.6.4 ***Polarity***

4.6.5 ***Operating Temperature Test Series***

4.6.5.1 ***Temperature Sensor Characteristics***

4.6.5.2 ***Warm-Up Time***

4.6.5.3 ***Operating Temperature***

4.6.6 ***Pickoff Test Series***

4.6.6.1 ***Scale Factor***

4.6.6.2 ***Scale Factor Composite Error***

4.6.6.3 ***Electrical Null***

4.6.6.4 ***Phase Shift***

4.6.7 ***Torquer Test Series***

4.6.7.1 ***Command Rate Scale Factor***

4.6.7.2 ***Command Rate Scale Factor Composite Error***

4.6.7.3 ***Maximum Command Rate***

4.6.7.4 ***Continuous Command Rate***

4.6.8 ***Rotor Rotation Detector***

4.6.9 ***Spin Motor Test Series***

4.6.9.1 ***Run-Up Time***

4.6.9.2 ***Run-Down Time***

4.6.9.3 ***Power Consumption***

4.6.10 ***Axis Alignment***

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4.6.11 ***Input Angle Test Series***

4.6.11.1 ***Input Limit***

4.6.11.2 ***Limit Stops***

4.6.12 ***Gyro Transfer Characteristic Test Series***

4.6.12.1 ***Gyro Scale Factor***

4.6.12.2 ***Gyro Gain***

4.6.12.3 ***Characteristic Time***

4.6.13 ***Drift Rate Test Series***

4.6.13.1 ***Acceleration-Insensitive Drift Rate***

4.6.13.2 ***Acceleration-Sensitive Drift Rate Coefficient***

4.6.13.3 ***Acceleration-Squared-Sensitive Drift Rate Coefficient***

4.6.13.4 ***Elastic Restraint Drift Rate Coefficient***

4.6.13.5 ***Gimbal Retardation (Gimbal Friction)***

4.6.13.6 ***Random Drift Rate***

4.6.14 ***Output Noise***

4.6.15 ***Dynamic Response Test Series***

4.6.15.1 ***Frequency Response***

4.6.15.2 ***Closed-Loop Step Response***

4.6.15.3 ***Settling Time***

4.6.16 ***Angular Acceleration Sensitivity About the Output Axis***

4.6.17 ***Generated Fields***

4.6.17.1 ***Electromagnetic Interference***

4.6.17.2 ***Magnetic Leakage***

4.6.18 ***Environmental Test Series***

4.6.18.1 ***Temperature***

4.6.18.2 ***Excitation Voltage and Frequency Variation***

4.6.18.3 ***Mechanical Shock***

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4.6.18.4 *Thermal Shock*

4.6.18.5 *Vibration*

4.6.18.6 *Acceleration*

4.6.18.7 *Mechanical Overload*

4.6.18.8 *Life*

4.6.18.8.1 *Storage*

4.6.18.8.2 *Operating*

4.6.18.9 *Fungus*

4.6.18.10 *Humidity*

4.6.18.11 *Salt Spray*

4.6.18.12 *Acoustical Noise*

4.6.18.13 *Thermal Radiation*

4.6.18.14 *Air Currents*

4.6.18.15 *Pressure*

4.6.18.16 *Nuclear Radiation*

4.6.18.17 *Magnetic Fields*

4.6.18.18 *Electromagnetic Fields*

4.6.18.19 *Sand and Dust*

4.6.18.20 *Sunshine*

4.6.18.21 *Rain*

Specific applications may require specific special tests, such as:

1) Thermal vacuum (Sections 4.6.18.1, 4.6.18.13, and 4.6.18.15)
2) Margin tests (Sections 4.6.18.1, 4.6.18.2, and 4.6.18.15)
3) Thermal shock/vacuum (Sections 4.6.18.4 and 4.6.18.15)

4.7 Data Submittal

The format for all data organization and the method of submittal shall be specified.

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5. Preparation for Delivery

Give detailed procedures for preservation and packaging, (2) packing, and (3) marking of shipping containers. A common United States specification covering preservation and packaging is MIL-P-116. Other organizations use different supporting documents.

6. Notes

6.1 Intended Use

Description of application if it is considered necessary or helpful.

6.2 Ordering Data

Procuring documents should specify the following:

1) Title, number, and date of this specification
2) Level of packaging and packing desired
3) Mode of shipment required
4) Whether sampling plan tests are to be conducted
5) Number of preproduction samples to be submitted for qualification testing

6.3 Model Equation

The model equation of a single-degree-of-freedom rate-integrating gyro is defined as a series which mathematically relates the output of a gyro to the several inputs applied to the gyro. The assumed model equation for the single-degree-of-freedom rate-integrating gyro when each term has the dimensions of angular velocity is:

$$\frac{J}{H}(\ddot{\Theta}_o + \ddot{\Phi}_o) + \frac{C}{H}\dot{\Theta}_o + \frac{K}{H}\Theta_o$$

$= \omega_I$ (rate, in inertial space, about the IA)

$+ D_{\mathrm{F}}$ (acceleration-insensitive drift rate)

$+ D_{\mathrm{I}}a_{\mathrm{I}} + D_{\mathrm{O}}a_{\mathrm{O}} + D_{\mathrm{S}}a_{\mathrm{S}}$ (acceleration-sensitive drift rate)

$+ D_{\mathrm{II}}a_{\mathrm{I}}^2 + D_{\mathrm{SS}}a_{\mathrm{S}}^2 + D_{\mathrm{IS}}a_{\mathrm{I}}a_{\mathrm{S}} + D_{\mathrm{IO}}a_{\mathrm{I}}a_{\mathrm{O}}$ (acceleration-sensitive drift rate)

$+ K_{\mathrm{T}}i$ (command rate)

The model equation stated is the result of summing torques about the OA, normalized to have dimensions of angular velocity by division by angular momentum. The sign convention chosen is such that a positive torque about the OA is associated with a positive rate.

For most of the testing required by this document, a steady-state version of the above equation may be used wherein the dynamic terms on the left side of the equation are zero.

Where significant, other terms could also be included in this expression such as cross-coupling terms due to misalignment, angular acceleration terms, etc.

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Symbols used in the model equation are defined as follows:

J = gimbal moment of inertia about the output axis
Θ_O = gimbal angular displacement about the output axis with respect to the case
Φ_O = case angular displacement about the output axis with respect to inertial space
C = damping coefficient about the output axis with respect to the case
H = rotor angular momentum
K = elastic restraint coefficient about the output axis with respect to the case
i = torquer command current
K_T = command rate scale factor

The polarity of K_T should be consistent with the polarity convention of Fig 1 and Sections 3.3.23.1 and 3.3.23.3. The preferred sign convention for K_T is (+).

For command rates that are generated by torquer inputs other than the first power of i (that is, variable reluctance torquers, pulse torquing, etc), the term $K_T i$ should be replaced with a command rate term consistent with the torquer or technique used and with the sign convention established.

The acceleration (a_I, a_O, a_S) used in the model equation are components of the vector sum of the apparent acceleration due to gravity and the second time derivative of a position vector in inertial space. On the earth, the positive direction of this apparent acceleration due to gravity is defined as that of an upward acceleration of the gyro case. In the model equation the terms are defined as follows:

a_I = acceleration component along the input axis
a_O = acceleration component along the output axis
a_S = acceleration component along the spin axis
D_F = drift rate that is insensitive to acceleration
$D_I a_I$ = drift rate attributable to acceleration along the input axis, where D_I is a drift rate coefficient
$D_O a_O$ = drift rate attributable to acceleration along the output axis, where D_O is a drift rate coefficient
$D_S a_S$ = drift rate attributable to acceleration along the spin axis, where D_S is a drift rate coefficient
$D_{II} a_I^2$ = drift rate attributable to the to the square of acceleration along the input axis, where D_{II} is a drift rate coefficient
$D_{SS} a_S^2$ = drift rate attributable to the square of acceleration along the spin axis, where D_{SS} is a drift rate coefficient
$D_{IO} a_I a_O$ = drift rate attributable to the product of accelerations along input axis and output axis, where D_{IO} is a drift rate coefficient
$D_{IO} a_I a_S$ = drift rate attributable to the product of accelerations along the input axis and the spin axis, where DIS is a drift rate coefficient
$D_{OS} a_O a_S$ = drift rate attributable to the product of accelerations along the output axis and spin axis, where D_{OS} is a drift rate coefficient
ω_I = angular velocity, with respect to inertial space, of the gyro case about the input axis

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Part II—Test Procedure

7. Scope

This test procedure describes the test requirements for _____ [model number, part number, change letter (if any), other identification], specification number _____, manufactured by _____.

8. Description

The rate-integrating gyro considered in this document is a single-degree-of-freedom gyro with a torquer capable of applying a restraint about the OA (output axis).

8.1 Angular Displacement Sensing

In the rate-integrating (displacement-sensing) mode, an angular rate about the IA (input axis) produces a gyroscopic torque about the OA that is opposed primarily by the viscous restraint. Static equilibrium is reached in a typical platform application when the gyro pickoff signal causes an external servo to restore the gyro gimbal to a null position. The rate-integrating gyro is normally used as a sensing element to provide angular displacement signals in control or indicating systems, or as a position reference element (such as in platform applications).

8.2 Angular Rate Sensing

In the rate-sensing mode, an angular rate about the IA produces a gyroscopic torque about the OA that is opposed by a restoring torque exerted by the gyro torquer through an external capture loop. Neglecting error torques, static equilibrium is reached when the gyroscopic torque about the OA is exactly balanced by the torquer. The torquer current provides an output signal that is a function of the angular rate about the IA.

8.3 Model Equation

The dynamics of the gyro are expressed by the equation given in Section 6.3.

9. Test Conditions and Test Equipment

9.1 Standard Test Conditions

Unless otherwise stated, the following conditions apply.

9.1.1 *Ambient Environment*

9.1.1.1 *Atmospheric Conditions*

1) Pressure: _____ ± _____ [Pa, in Hg]
2) Ambient temperature: _____ ± _____ °C
3) Relative humidity: _____ to _____ percent

9.1.1.2 *Magnetic Field*

1) Horizontal component: _____ [G, mT] maximum

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2) Vertical component: _____ [G, mT] maximum
3) Method of measurement shall be as specified in Section _____

9.1.1.3 *Radiation*

List type of radiation and applicable intensity limits.

9.1.1.4 *Vibration*

1) Acceleration: _____ *g* maximum
2) Frequency range: _____ to _____ Hz

The preceding limits apply to each of the three axes of a coordinate system.

9.1.2 *Installation Conditions*

In designing the mounting fixture, consideration shall be given to the installation conditions of the application

Reference to a specific mounting block thermal and mechanical design, etc, may be necessary if deemed important to meet performance requirements.

9.1.2.1 *Thermal Conditions*

All tests shall be performed with the unit at thermal equilibrium as evidenced by _____.

The unit operating temperature shall be _____ ± _____ °C.

Determination of the temperature shall be as specified in Section_____.

9.1.2.2 *Mechanical Conditions*

The gyro shall be mounted in such a way that the alignment of its three reference axes with respect to the test fixture is established and maintained within _____ [arc seconds, _____] under all specified test conditions.

9.1.3 *Electrical Excitation and Load Conditions*

Excitation and load conditions shall be as specified hereinafter.

9.1.3.1 *Spin Motor*

1) Frequency: _____ ± _____ Hz
2) Type of connection [3 phase, 3 wire delta, _____]
3) Line-to-line voltage: _____ ± _____ V
4) Phase angle: _____ ± _____ °
5) Wave characteristic shall be _____

Wave shape, harmonic distortion, etc, shall be specified.

6) Source impedance: _____ ± _____ Ω [+, –]*j* _____ ± _____ Ω
7) Phase-splitting capacitor: _____ ± _____ μF

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9.1.3.2 *Pickoff*

1) Frequency: _____ [± _____ Hz, phase locked with spin motor excitation]
2) [Voltage, Current] _____ ± _____ [V, mA]
3) Maximum [voltage, current] waveform distortion: _____
4) Source impedance: _____ ± _____ Ω [+, –]*j* _____ ± _____ Ω
5) Load impedance: _____ ± _____ Ω [+, –]*j* _____ + _____ Ω

9.1.3.3 *Torquer*

1) Frequency: _____ ± _____ Hz
2) Reference current: _____ ± _____ mA
3) Maximum reference current waveform distortion: _____
4) Reference current source impedance: _____ ± _____ Ω [+, –]*j* _____ ± _____ Ω
5) Control current source impedance: _____ ± _____ Ω [+, –]*j* _____ ± _____ Ω

9.1.3.4 *Rotor Rotation Detector*

Load impedance: _____ ± _____ Ω [+, –]*j* _____ ± _____ Ω.

9.1.3.5 *Warm-Up Heater*

1) Frequency: _____ ± _____ Hz
2) Voltage: _____ ± _____ V

9.1.3.6 *Control Heater*

1) Frequency: _____ ± _____ Hz
2) Voltage: _____ ± _____ V
3) Type of control: _____

9.1.3.7 *Temperature Sensor*

1) Frequency: _____ ± _____ Hz
2) Voltage: _____ ± _____ V

9.1.3.8 *Gimbal Suspension*

Other electrical and load conditions that are required for gyros with floated-electrostatic or magnetic centering suspensions and for hydrostatic fluid-bearing suspensions with an internal pump shall be specified.

9.1.3.9 *Phasing and Interconnection*

Interconnection and grounding shall be as specified on schematic diagram _____.

9.1.4 *Starting Procedure*

9.1.4.1 *Warm-Up Time*

Unless otherwise specified, a warm-up time of _____ minutes is allowed before starting the tests of Section 10.

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9.1.4.2 *Starting Sequence*

The sequence of operations required to bring the gyro to operating condition shall be _____.

9.1.5 *Turn-Off Procedure*

The sequence of operations required to turn off the gyro shall be _____

9.2 Standard Operating and Test Equipment

9.2.1 *General Requirements*

The accuracy and bandpass characteristics of the test equipment shall be compatible with the requirements of the gyro performance specification. Provision shall be made for adequate stabilization of the test equipment. When possible, adequate limitations shall be placed on the test equipment to protect the gyro from excessive inputs and loads, such as electrical, mechanical, thermal, etc.

9.2.2 *Standard Operating Equipment*

Standard operating equipment is the equipment used to provide standard gyro operation and shall be listed here by name, manufacturer, model, part number, or by performance requirements.

9.2.3 *Test Equipment*

Test equipment is the equipment used to provide a stimulus or a measurement capability and shall be listed here by name, manufacturer, model, part number, or by performance requirements.

10. Test Procedures

10.1 Examination of Product (Mechanical)

The gyro shall be inspected visually and dimensionally for proper identification, surface finish, and for defects in workmanship to mine that it conforms to the requirements of Section _____.

10.2 Examination of Product (Electrical)

The gyro shall be inspected electrically according to the following sections to measure impedances, dielectric strengths, and insulation resistances.

10.2.1 *Impedance Test*

10.2.1.1 *Purpose*

The purpose of this test is to measure the impedance of the pickoff, motor, torquer, rotor rotation detector, and heater circuits.

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10.2.1.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Impedance bridge with frequency generator adjustable to the specified frequency
2) DC resistance bridge or other suitable resistance measuring system

10.2.1.3 *Test Setup and Procedure*

The gyro shall be allowed to reach thermal equilibrium at the temperature specified in Sections _____ in order that the final value will not be affected by changing temperature.

Measure all gyro impedances specified in Section _____ . The test current through the circuit shall be as small as practical considering the sensitivity of the measuring instruments. The test current shall be uninterrupted for _____ ± _____ seconds.

10.2.1.4 *Test Results*

The impedance quantities measured shall be recorded and shall conform to the requirements of Sections _____.

10.2.2 *Dielectric Test*

10.2.2.1 *Purpose*

The purpose of this test is to ascertain that a circuit element or component part of the gyro can operate safely at its rated voltage and withstand momentary overpotentials due to switching, surges, etc, by measuring the leakage current between isolated circuits and between the gyro case and the circuits isolated from the gyro case.

10.2.2.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

AC high-voltage source equipped with voltage and current-measuring devices

10.2.2.3 *Test Setup and Procedure*

Apply _____ ± _____ V rms at _____ Hz between the insulated portion and the case ground. The test voltage shall be raised from zero to the specified value as uniformly as possible, at a rate of approximately 500 V rms per second. The test voltage shall be maintained for a period of _____ seconds. At this time, the voltage shall be gradually reduced to avoid surges. During each test, the fault indicator shall be monitored for the leakage current.

10.2.2.4 *Test Results*

The results shall conform to the requirement of Section _____.

10.2.3 *Insulation Resistance*

10.2.3.1 *Purpose*

The purpose of this test is to measure the insulation resistance between the isolated electrical circuits and between the gyro case and the circuits isolated from the gyro case.

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10.2.3.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section: Megohmmeter

10.2.3.3 *Test Setup and Procedure*

Apply _____ ± _____ V dc for a period of _____ ± _____ seconds between the indicated circuits and between the circuits and the gyro case. Record the final resistance reading,

10.2.3.4 *Test Results*

The results shall conform to the requirement of Section _____.

10.3 Leak Test

10.3.1 *Purpose*

The purpose of this test is to determine if leakage through the gyro case is occurring.

10.3.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section: *Fluid seal gyro* 1) Binocular microscope 2) Vacuum enclosure *Gas seal gyro* 1) Helium leak detector or immersion fluid (specify) 2) Vacuum enclosure

10.3.3 *Test Setup and Procedure*

10.3.3.1 *Fluid Seal Gyro*

The gyro shall be cleaned of all dirt and grease and placed in a vacuum enclosure at _____ ± _____ [Pa, torr] and at a gyro temperature of _____ ± _____ °C for a minimum period of _____ hours. The gyro shall then be removed and visually examined at a magnification of _____.

Chemical reaction tests may also be used to detect fluid leakage.

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10.3.3.2 *Gas Seal Gyro*

10.3.3.2.1 *Method 1*

The gyro shall be cleaned of all dirt and grease and placed in a vacuum enclosure at _____ ± _____ [Pa, torr] and stabilized at _____ ± _____ °C gyro temperature. External gas leakage shall then be measured using a helium gas detector.

10.3.3.2.2 *Method 2*

The gyro shall be cleaned of all dirt and grease and submerged in fluid and placed in a vacuum enclosure at _____ ± _____ [Pa, torr] and. _____ ± _____ °C gyro temperature for a period of minutes. The presence or absence of a continuous flow of bubbles shall be noted.

10.3.4 *Test Results*

10.3.4.1 *Fluid Seal Gyro*

There shall be no evidence of external fluid leakage.

10.3.4.2 *Gas Seal Gyro*

10.3.4.2.1 *Method 1*

The measured gas leakage rate shall not exceed _____ cm^3/s.

10.3.4.2.2 *Method 2*

There shall be no evidence of a steady stream of bubbles after _____ minutes.

10.4 Polarity

10.4.1 *Purpose*

The purpose of the polarity test is to determine the gyro pickoff, torquer, and motor polarities with reference to the axes defined in Section _____ of the specification.

10.4.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Single-axis rate table
2) Means of measuring in-phase component of the gyro pickoff output

10.4.3 *Test Setup and Procedure*

10.4.3.1 *Pickoff*

Mount the gyro on the single-axis rate table with the gyro ORA output reference axis) nominally parallel to the table axis. Connect the gyro to the output measuring equipment. Prepare the gyro for test in accordance with the standard test conditions of Section 9.1, but do not apply wheel excitation. Accelerate the table to less than _____ ° /s with the input vector in the same direction as the positive output axis until indication of the gyro output polarity is obtained.

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Record the polarity in similar manner in the opposite direction and again record the polarity of the gyro output with respect to the pickoff excitation.

> Positive acceleration of the case about the ORA produces a negative relative displacement of the gimbal with respect to the case.
>
> The pickoff polarity test must be successfully concluded before checking the motor and torquer polarities.

10.4.3.2 *Torquer*

With the gyro mounted and operated as in Section 10.4.3.1, apply a positive input of _____ mA to the torquer. Record the polarity of the pickoff output. Repeat this procedure for a negative torquer input.

10.4.3.3 *Motor*

Mount the gyro on the single-axis rate table with the gyro IRA (input reference axis) nominally parallel to the table axis. Connect the gyro to the output measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1. Rotate the table at _____ ° /h with the input vector in the same direction as the positive input axis until an indication of the gyro output polarity is obtained. Record the polarity of the pickoff output. Repeat for the opposite table rotation.

10.4.4 *Test Results*

10.4.4.1 *Pickoff*

The results obtained in Section 10.4.3.1 shall conform to the requirements of Section _____.

10.4.4.2 *Torquer*

The result obtained in Section 10.4.3.2 shall conform to the requirement of Section.

10.4.4.3 *Motor*

The result obtained in Section 10.4.3.3 shall conform to the requirement of Section _____.

10.5 Operating Temperature Test Series

10.5.1 *Temperature Sensor Characteristics*

10.5.1.1 *Purpose*

The purpose of this test is to determine the resistance (operating temperature) and scale factor (near operating temperature) of the gyro temperature sensor.

> If an internal gyro element other than the internal temperature sensor is to be used, a similar test shall be specified for that element.

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10.5.1.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Temperature control oven
2) Resistance-measuring equipment

10.5.1.3 *Test Setup and Procedure*

Operate the gyro in a temperature-controlled oven with the standard test conditions of Section 9.1, but with the sensor and heaters de-energized. Stabilize the gyro temperature for _____ minutes at _____ ± _____ °C (operating temperature). Measure the resistance of the temperature sensor utilizing the resistance-measuring equipment.

Repeat these measurements at the following ambient temperatures: _____ and _____ ± _____ °C.

One of the temperatures should be above and one below the operating temperature.

During this test, the power to the sensor shall not exceed W. Record oven temperatures and sensor resistance at the three temperatures.

10.5.1.4 *Test Results*

The resistance of the sensor at the nominal operating temperature shall be _____ ± _____ Ω.

From the off-nominal temperature data, compute the change in resistance per unit temperature.

The result shall be _____ ± _____ [Ω/K, Ω/°C].

If the gyro utilizes a thermostatic temperature control instead of a resistive sensor, the temperature at which the device opens on a rising temperature and closes on a falling temperature should be measured. The rate of temperature change should also be specified.

10.5.2 *Warm-Up Time*

10.5.2.1 *Purpose*

The purpose of this test is to determine the time interval required for the gyro to reach operating temperature from the instant that it is energized under specified operating conditions.

A separate test may be run to specify the time to reach a particular performance parameter if necessary.

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10.5.2.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed here:

1) Means of measuring elapsed time
2) Temperature-measuring equipment
3) Resistance-measuring equipment
4) Temperature chamber (if required)

10.5.2.3 *Test Setup and Procedure*

Connect the gyro temperature-sensing element(s) to the output measuring/recording equipment.

Operate the gyro in accordance with the standard test conditions of Section 9.1, except that the thermal and mechanical starting conditions shall be _____ and the starting sequence shall be _____.

Energize the gyro and record the indicated temperature(s) as a function of time until _____ minutes after operating temperature is achieved.

10.5.2.4 *Test Results*

The time for all indicated temperatures to stabilize to within the operating temperature limits required in Section _____ shall conform to the warm-up requirements of Section _____.

10.5.3 *Operating Temperature*

10.5.3.1 *Purpose*

The purpose of this test is to insure that the gyro operating temperature is within the operating temperature range as indicated by the [self-contained temperature sensor resistance, spin-motor resistance, torquer resistance, _____].

10.5.3.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Temperature-measuring equipment
2) Temperature chambers (if required)
3) Resistance-measuring equipment

10.5.3.3 *Test Setup and Procedure*

Operate the gyro in accordance with the standard test conditions of Section 9.1. The gyro shall be allowed to reach thermal equilibrium for _____ minutes before the temperature measurement is made. Measure and record the [temperature of the _____, resistance of the _____, _____].

10.5.3.4 *Test Results*

The gyro operating temperature shall be within the operating temperature range specified in Section _____.

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10.6 Pickoff Test Series

10.6.1 *Purpose*

The purpose of this test is to measure the pickoff scale factor, scale factor composite error, electrical null, and phase shift.

10.6.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Means of measuring phase shift
2) Means of positioning the gyro case accurately about the ORA
3) Means of measuring in-phase quadrature, and total pickoff output voltages
4) Single-axis rate table
5) Gyro torquer supply

10.6.3 *Test Setup and Procedure*

10.6.3.1 *Scale Factor and Scale Factor Composite Error*

Mount the gyro in the fixture on the single-axis rate table with the SRA (spin-reference axis) nominally parallel to the table axis. Connect the gyro to the pickoff output measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1.

Rotate the test table at a nominal rate of _____ ° /s with the input vector in the same direction as the SRA. Record the pickoff output. Stop the table rotation. Reorient the gyro about the ORA_____ ± _____ ° and repeat the above procedure. Repeat at _____ ° steps to + _____ ° and – _____ °.

With the spin motor running, rotation about an axis perpendicular to the ORA will cause the SA (spin axis) to align itself with the input vector as accurately as gyro geometry and restraints will allow. The rate table angular velocity should be high enough that a further increase in rate causes no appreciable change in gyro pickoff output.

An accurate knowledge of pickoff scale factor may not be necessary for closed-loop operation of the single-degree-of-freedom integrating gyro. A simple check of the pickoff scale factor can be made using the torquer to rotate the gyro gimbal to the limit stops and measuring the pickoff output. This method is limited by the accuracy to which the mechanical location of the limit stops is known.

10.6.3.2 *Phase Shift and Electrical Null*

Mount the gyro in a fixture. Connect the gyro to the phase-measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1. Using the gyro torquer, rotate the gimbal in the _____ direction until an output of _____ ± _____ V rms is obtained. Measure the phase shift between the pickoff output and the pickoff excitation. Repeat with the gimbal rotated in the opposite direction from null.

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Using the torquer, rotate the gyro gimbal until the pickoff output at the previously measured phase angle is a minimum. Record this voltage as the in-phase null, a voltage 90° out-of-phase with this voltage as the quadrature voltage, and the total voltage.

The output voltage chosen for the phase-shift measurement should be large enough to make the errors due to quadrature insignificant. This test may be performed in a closed loop using an offset signal in the balance loop to produce the desired output.

10.6.4 *Test Results*

10.6.4.1 *Pickoff Scale Factor*

Obtain the slope of the best straight line that can be fitted by a method, such as the method of least squares, to the input-output data obtained in Section 10.6.3.1. Pickoff scale factor as computed above shall conform to the requirements of Section _____.

10.6.4.2 *Scale Factor Composite Error*

Pickoff scale factor composite error stated as a percent of the maximum specified pickoff output is the maximum deviation of the input-output data obtained in Section 10.6.3.1 from the nominal pickoff scale factor requirement. The pickoff scale factor composite error shall conform to the requirements of Section _____.

10.6.4.3 *Electrical Null*

The voltages measured in Section 10.6.3.2 shall conform to the requirements of Section _____.

10.6.4.4 *Phase Shift*

The phase shifts measured in Section 10.6.3.2 shall conform to the requirements of Section _____.

10.7 Torquer Test Series

10.7.1 *Purpose*

The purpose of this test is to measure command rate scale factor, command rate scale factor composite error, maximum command rate, and continuous command rate.

10.7.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Single-axis rate table
2) Single-axis servo table
3) Single-axis dividing head
4) Gyro capture electronics
5) Gyro torquer supply
6) Means of measuring gyro torquer current
7) Means of measuring in-phase component of gyro pickoff output
8) Timing device

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10.7.3 *Test Setup and Procedure*

10.7.3.1 *Scale Factor and Scale Factor Composite Error*

10.7.3.1.1 *High Input Rate Test*

Align the servo table rotational axis to within _____ arc seconds of vertical. Mount the gyro in the fixture on the servo table so that the IA is parallel to the table rotational axis within _____ arc seconds. Connect the gyro into the servo table loop and to the measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1. Starting at the specified negative continuous command rate, vary the input to the torquer cyclically over the input span in steps of _____ mA. Record the torquer current and table rate at each step.

10.7.3.1.2 *Low Input Rate Test*

Align the dividing head spindle axis to within _____ arc seconds of vertical. Mount the gyro in the fixture on the dividing head so that the IA is perpendicular to the spindle axis within _____ arc seconds and the ORA is nominally vertical. Connect the gyro to the gyro capture electronics and measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1. Rotate the dividing head to orient the gyro IA south within arc minutes. Record the dividing head angle and the gyro torquer current. Rotate the dividing head through 360° in _____ steps of _____ ± _____ °. At each step, record the dividing head angle and the corresponding torquer current.

10.7.3.2 *Maximum Command Rate*

Align the rate table rotational axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the rate table so that the IA is parallel to the table rotational axis within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Apply an input rate of _____ ± _____ ° /s for no longer than _____ seconds. Within _____ minutes after removal of maximum command rate, complete a repetition of the test of Section 10.7.3.1.1 or Section 10.7.3.1.2.

> This test may also be performed by operating the gyro in a servo table loop, by applying an external signal to the torquer equivalent to the specified command rate, and by measuring the table rate.

10.7.3.3 *Continuous Command Rate*

Align the rate table rotational axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the rate table so that the IA is parallel to the table rotational axis within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Apply an input rate of _____ ± _____ ° /s for at least _____ minutes. Within minutes after removal of the continuous command rate, complete a repetition of the test of Section 10.7.3.1.1 or Section 10.7.3.1.2.

> This test may also be performed by operating the gyro in a servo table loop, by applying an external signal to the torquer equivalent to the specified command rate, and by measuring the table rate.

10.7.4 *Test Results*

10.7.4.1 *Command Rate Scale Factor K_T*

> The recommended analysis for Section 10.7.3.1.1, High Input Rate Test, is a linear least squares fit; for Section 10.7.3.1.2, Low Input Rate Test, a Fourier fit that includes only the constant and fundamental terms is recommended.

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10.7.4.1.1 *High Input Rate Test*

The slope of the best straight line that can be fitted to the input-output data obtained in Section 10.7.3.1.1 is the command rate scale factor and shall conform to the requirements of Section _____.

10.7.4.1.2 *Low Input Rate Test*

Determine the amplitude of the fundamental by fitting the input-output data of Section 10.7.3.1.2 using a Fourier analysis. Using this amplitude, compute the command rate scale factor:

$$\text{command rate scale factor} = \frac{\text{horizontal component of earth's rate [° /s, ° /h]}}{\text{amplitude of fundamental [mA]}}$$

The command rate scale factor as computed above shall conform to the requirements of Section _____.

10.7.4.2 *Command Rate Scale Factor Composite Error*

Command rate scale factor composite error stated as a percent of the continuous command rate is the maximum deviation of the input-output data from the best fit curves obtained in either Section 10.7.4.1.1 or Section 10.7.4.1.2. The command rate scale factor composite error as computed above shall conform to the requirements of Section _____.

10.7.4.3 *Maximum Command Rate*

Command rate scale factor and command rate scale factor composite error shall conform to the requirements of Section _____ , following exposure to the specified maximum command rate.

10.7.4.4 *Continuous Command Rate*

Command rate scale factor and command rate scale factor composite error shall conform to the requirements of Section _____ , following exposure to the specified continuous command rate.

10.8 Rotor Rotation Detector

10.8.1 *Purpose*

The purpose of this test is to measure the output of the RRD (rotor rotation detector).

10.8.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Means of measuring the frequency
2) Means of measuring the waveform characteristics

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10.8.3 *Test Setup and Procedure*

10.8.3.1 *Pulse Output Type*

Connect the RRD to the output measuring equipment and operate the gyro in accordance with the standard test conditions of Section 9.1. Measure the zero-to-peak voltage of the smallest and largest peaks. Measure the pulse width at _____ V of the narrowest and the widest pulses. Measure the repetition rate. Measure the [rise, fall] time.

10.8.3.2 *Near Sinusoidal Output Type*

Connect the RRD to the output measuring equipment and operate the gyro in accordance with the standard test conditions of Section 9.1. Measure the rms voltage of the total output and the frequency and amplitude of the fundamental signal.

10.8.4 *Test Results*

The results obtained in Section [10.8.3.1, 10.8.3.2] shall conform to the requirements of Section _____.

10.9 Spin Motor Test Series

10.9.1 *Purpose*

The purpose of this test series is to measure the spin motor run-up time, run-down time, the starting power, the running power, and the starting and running current.

10.9.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Means of measuring elapsed time
2) Means of measuring rotor speed
3) Means of measuring power
4) Means of measuring current

10.9.3 *Test Setup and Procedure*

10.9.3.1 *Run-Up Time*

Prepare the gyro for test in accordance with the standard test conditions of Section 9.1, except do not apply wheel excitation. Excite the spin motor and simultaneously start the timer. When the rotor reaches [a speed of _____ r/min, synchronous speed] stop the timer and record the elapsed time.

10.9.3.2 *Run-Down Time*

Operate the gyro in accordance with the standard test conditions of Section 9.1. Remove the spin motor excitation. Start the timer when the rotor reaches _____ r/min. When the rotor reaches _____ r/min, stop the timer and record the elapsed time.

If the run-down time is measured under other than open-circuit conditions, load conditions should be defined.

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10.9.3.3 Power Consumption (Starting Power, Running Power, Starting and Running Current)

Connect the power and current measuring devices in the circuit between the spin motor power supply and the spin motor. Prepare the gyro for test in accordance with the standard test conditions of Section 9.1, except do not apply wheel excitation. Apply power to the spin motor; measure and record the starting current and power. Allow the rotor to reach operational speed; measure and record the running power and current.

10.9.4 *Test Results*

10.9.4.1 *Run-Up Time*

The results of Section 10.9.3.1 shall conform to the requirements of Section _____.

10.9.4.2 *Run-Down Time*

The results of Section 10.9.3.2 shall conform to the requirements of Section _____.

10.9.4.3 *Power Consumption (Starting and Running Power, Starting and Running Current)*

The results of Section 10.9.3.3 shall conform to the requirements of Section _____.

10.10 Axis Alignment

10.10.1 *Purpose*

The purpose of this test is to measure the misalignment of the IRA to the projection of the IA on the IRA-SRA plane and the misalignment of the IA to the IRA-SRA plane.

10.10.2 Test Equipment

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for these tests and shall be listed in this section:

1) Single-axis rate table
2) Gyro capture electronics
3) Means of measuring the gyro pickoff output
4) Means of measuring the gyro torquer current

10.10.3 Test Setup and Procedure

10.10.3.1 *Alignment of the IRA to the Projection of the IA on the IRA-SRA Plane*

Align the rate table rotational axis within _____ arc seconds of vertical. Mount the gyro in the fixture on the rate table so that the SRA is parallel to the rate table rotational axis within arc seconds. Connect the pickoff to the pickoff output measuring equipment. Operate the gyro in accordance with the standard test conditions of Section 9.1. Apply a

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table rate of _____ ± _____ °/s, in the same sense as the SRA. After revolutions minimum, measure the average pickoff output voltage over a complete revolution.

> The rate about the SRA should be large enough to make the effects of gyro drift rates and the horizontal component of earth's rate negligible.
>
> To eliminate test fixture errors, it may be desirable to rotate the gyro 180° about the ORA with respect to the fixture and repeat the test.
>
> The test may also be performed by operating the gyro in the rate-sensing mode (Section 8.2).

10.10.3.2 *Alignment of the IA to the IRA-SRA Plane*

Align the rate table rotational axis to within _____ arc seconds of vertical. Mount the gyro on the fixture on the rate table so that the ORA is parallel to the table axis of rotation to within arc seconds. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the gyro to the torquer current measuring equipment. Apply an input rate of _____ ± _____ °/s about the ORA for _____ revolutions of the rate table. Measure the average torquer current. Reverse the direction of the table rotation and repeat the preceding test.

> To eliminate test fixture errors, it may be desirable to rotate the gyro 180° about the ORA with respect to the fixture and repeat the test for both directions of the table rotation.
>
> If alignment stability is specified, direction of table rotation and current polarity must be recorded.

10.10.4 *Test Results*

10.10.4.1 *Alignment of the IRA to the Projection of the IA on the IRA-SRA Plane*

The misalignment is calculated from the data obtained in Section 10.10.3.1 and the [pickoff scale factor from Section 10.6.4.1, nominal pickoff scale factor] as follows:

$$\text{misalignment} = \frac{\text{average pickoff output (V)}}{\text{pickoff scale factor (V/°)}}$$

The results shall conform to the requirements of Section _____.

10.10.4.2 *Alignment of IA to the IRA-SRA Plane*

The misalignment is calculated from the data obtained in Section 10.10.3.2 and the command rate scale factor (Section 10.7.4.1) as follows:

$$\text{misalignment} = \frac{\text{difference between the two average currents} \times \text{command rate scale factor}}{2 \times \text{table rate}}$$

The results shall conform to the requirements of Section _____.

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10.11 Input Angle Test Series

10.11.1 *Purpose*

The purpose of this test series is to determine that the gyro meets the specified input limit and limit stop requirements.

10.11.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for these tests and shall be listed in this section:

1) Dividing head
2) Gyro torquer supply
3) Means of measuring the pickoff output

10.11.3 Test Setup and Procedure

10.11.3.1 *Input Limit*

Align the dividing head spindle axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the dividing head so that the gyro IA is parallel to the spindle axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the precision current source to the gyro torquer and connect the pickoff to the pickoff output measurement equipment. Adjust the torquer current until the pickoff output remains at null. (The output shall not change more than _____ mV/min.)

Rotate the dividing head through a positive input angle of _____ ± _____ °. The input motion shall be smooth, continuous, and unidirectional. Record the pickoff output, return the dividing head to the initial orientation, and verify that the gyro output returns to null within _____ mV. Repeat the above procedure, except rotate the dividing head through a negative input angle of _____ ± _____ °.

The test input angles and the output measurement must be accomplished within a time frame that limits errors introduced by gyro drift rate.

10.11.3.2 Limit Stops

10.11.3.2.1 *Method 1, Input Angle Test*

Align the dividing head spindle axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the dividing head so that the IA is parallel to the spindle axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the current source to the gyro torquer control winding and connect the pickoff to the pickoff output measurement equipment. Adjust the torquer current until the pickoff output remains stable at null within mV/min.

Rotate the dividing head until the gimbal reaches the positive limit stop (maximum pickoff output). Continue rotating the dividing head in the same direction to a dividing head reference angle. Rotate the dividing head in the reverse direction to drive the gimbal to null within _____ mV and record the corresponding dividing head angle. The input motion shall be smooth, continuous, and unidirectional.

Repeat for the negative limit stops.

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10.11.3.2.2 *Method 2, Pickoff Output Test*

Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the current source to the gyro torquer. control winding and connect the pickoff to the pickoff output measurement equipment. Excite the torquer with a current of _____ mA to produce a positive pickoff output. Measure the maximum pickoff output.

Repeat for a negative pickoff output.

The current level must be large enough to drive the gimbal to the limit stop.

10.11.4 *Test Results*

10.11.4.1 *Input Limit*

Compute the input limit for both positive and negative inputs as follows:

$$\text{input} = \frac{\text{pickoff output}}{\text{gyro scale factor}}$$

10.11.4.2 *Limit Stops*

10.11.4.2.1 *Method 1, Input Angle Test*

The results shall conform to the requirements of Section _____.

10.11.4.2.2 *Method 2, Pickoff Output Test*

Compute the positive and negative limit stops as follows:

$$\text{limit stops} = \frac{\text{maximum pickoff output}}{\text{gyro scale factor}}$$

The gyro scale factor shall be that determined in Section _____. The results shall conform to the requirements of Section _____.

10.12 Gyro Transfer Characteristic Test Series

10.12.1 *Purpose*

The purpose of this test series is to determine the gyro scale factor, gyro gain, and gyro characteristic time.

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10.12.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Servo table
2) Oscillating rate table
3) Means of measuring gyro pickoff out-put
4) Gyro torquer supply
5) Dividing head
6) Means of measuring phase shift

10.12.3 *Test Setup and Procedure*

10.12.3.1 *Gyro Scale Factor*

10.12.3.1.1 *Method 1*

Mount the gyro in the fixture on the servo-driven table so that the gyro IA is parallel to the table rotational axis within _____ arc minutes and the servo-driven table rotational axis is nominally vertical. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the gyro pickoff output to the output recording equipment and connect the torquer current supply to the gyro torquer. Connect the table angular position output device to the servo-driven table position recording equipment. Adjust the torquer current to hold the gyro pickoff output at null. The output shall not change more than _____ mV/min.

Drive the servo table to the gyro negative input angle limit, reverse the table drive direction, and drive the table to the positive input angle limit, reverse the direction, and return to the negative input angle limit. Return the table to its initial position within _____ arc seconds. Verify that the gyro pickoff output returns to null within _____ mV and that the output does not change more than _____ mV/min. The gyro pickoff output recording shall be examined to verify that neither gyro limit stop has been contacted.

The table position recording and the gyro pickoff output recording must be time correlated. The compensated gyro drift rate must be small enough to insure that the drift angle accrued during the test causes no significant error. The table drive rate should be high enough that uncompensated drift rate and gyro elastic restraint cause no significant measurement error.

10.12.3.1.2 *Method 2*

Align the dividing head spindle axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the dividing head so that the IA is parallel to the spindle axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the gyro pickoff output to the output measuring equipment and the gyro torquer to the current supply. Adjust the torquer current to maintain the pickoff output at null. Rotate the dividing head clockwise _____ ± _____ [arc minutes, °]. Record the input angle and the corresponding pickoff output. (Select an input angle approximately one-half the input limits.) Return the dividing head to the initial position and verify that the pickoff is at null within _____ mV. Readjust torquer current to maintain null. Repeat the above except for counterclockwise rotation of the dividing head. Repeat the clockwise and counterclockwise measurements _____ times.

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10.12.3.2 *Gyro Gain*

No test required. Gyro gain is calculated as indicated in Section 10.12.4.2.

10.12.3.3 *Characteristic Time*

10.12.3.3.1 *Method 1*

Align the oscillating rate table axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the table so that the gyro OA is parallel to the table rotational axis within _____ arc seconds. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the gyro torquer to the current supply. Adjust the torquer current to maintain the pickoff output at null. The output shall not change more than _____ mV/min.

Connect the table rate monitoring signal and the gyro pickoff output to the phase measuring equipment. Operate the oscillating rate table at an amplitude which is sufficient to generate an easily discernible signal from the pickoff, but not so high as to cause the gimbal to contact the stops. Vary the frequency of the rate table drive until the phase measurement equipment indicates a phase difference of 45 ± _____ °. Record the table drive frequency.

10.12.3.3.2 *Method 2*

Align the oscillating rate table axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the table so that the gyro OA is parallel to the rotational axis within _____ arc minutes. Prepare the gyro for test in accordance with the standard test conditions of Section 9.1, except do not apply normal wheel excitation. Connect the gyro torquer to the current supply. Adjust the torquer current to maintain the pickoff output at null.

It may be necessary to approximate the normal fluid damping by supplying equivalent power to the spin motor without causing wheel rotation.

Connect the table rate monitoring signal and the gyro pickoff output to the phase measuring equipment. Operate the oscillating rate table at an amplitude that is sufficient to generate an easily discernible signal from the pickoff, but not so high as to cause the gimbal to contact the stops. Vary the frequency of the table rate drive until the phase measurement equipment indicates a phase difference of 45 ± _____ °. Ρεχορδ τηε ταβλε δριϖε φρεθυενχψ.

Characteristic time is meaningful only for a gyro which may be adequately represented by a second-order model equation. For other gyros, complete dynamic testing may be required.

If an accurate determination of characteristic time is not required, it can be calculated using reference constants $T = J/C$.

10.12.4 *Test Results*

10.12.4.1 *Gyro Scale Factor*

10.12.4.1.1 *Method 1*

Obtain the slope of the straight line fitted by the method of least squares to the input-output data obtained in Section 10.12.3.1.1. The gyro scale factor as computed above shall conform to the requirements of Section _____.

10.12.4.1.2 *Method 2*

Calculate the gyro scale factor from the data obtained in Section 10.12.3.1.2 as the ratio of the average change in pickoff output voltage to the selected change in dividing head angle.

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The gyro scale factor as computed above shall conform to the requirements of Section _____.

10.12.4.2 *Gyro Gain*

Using the value of pickoff scale factor determined in Section 10.6.4.1 and the value of gyro scale factor determined in Section 10.12.4.1, compute the gyro gain as follows:

$$\text{gyro gain} = \frac{\text{gyro scale factor (V/°)}}{\text{pickoff scale factor (V/°)}}$$

The result shall conform to the requirement of Section _____.

10.12.4.3 *Characteristic Time*

Calculate the characteristic time as the inverse of the frequency in radians per second recorded in Section 10.12.3.3. The characteristic time as computed above shall conform to the requirements of Section _____.

10.13 Drift Rate Test Series

10.13.1 *Purpose*

The purpose of this test series is to measure the gyro acceleration-sensitive drift rate, acceleration-sensitive, and acceleration-squared-sensitive drift rate coefficients, elastic restraint drift rate coefficient, gimbal retardation (gimbal friction), and random drift rate; and to determine the repeatability of the acceleration-insensitive drift rate and acceleration-sensitive drift rate coefficients.

10.13.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for these tests and shall be listed in this section:

1) Dividing head
2) Servo table
3) Means of measuring gyro torquer current
4) Means of recording gyro torquer current
5) Means of measuring gyro pickoff output
6) Means of measuring gyro in phase pickoff output
7) Gyro capture electronics
8) Gyro torquer supply
9) Voltage source offset pickoff signal
10) Single-axis linear vibration table
11) Means of measuring elapsed time
12) Ramp generator

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10.13.3 *Test Setup and Procedure*

10.13.3.1 *Acceleration-Insensitive Drift Rate, Acceleration-Sensitive and Acceleration-Squared-Sensitive Drift Rate Coefficients*

10.13.3.1.1 *Equatorial Tumble Method*

> If the acceleration-squared-sensitive drift coefficients are expected to be small, it is suggested that the vibration method be used for their determination. When the equatorial tumble method is used, care should be taken to minimize the effects of errors due to table misalignments with respect to the earth's polar axis and gyro misalignments with respect to the table. The orientation of the gyro for tumble testing should be selected from Appendix B, Table B.2, depending upon coefficients desired and assumptions to be made. See Fig B.1 for gyro and table orientations.

Orient the tumble table rotational axis parallel to earth's polar axis within _____ arc seconds. Mount the gyro in the fixture and align the [OA, SA] parallel to the table axis and [north, south] within _____ arc seconds.

Operate the gyro in the rate-sensing mode (Section 8.2), in accordance with the standard test conditions of Section 9.1. Connect the gyro to the torquer current recording equipment.

Drive the tumble table clockwise at [10, _____] times earth's rate ± _____ percent. Start the torquer current recorder when the gyro IA is horizontal within _____ arc seconds and directed east. Continuously record the torquer current while the tumble table rotates through at least _____ complete revolutions. Repeat for counterclockwise table rotation.

Repeat the above test for the following initial orientations.

> It is frequently desirable to allow for gyro gimbal to gyro case relative motion by specifying a minimum angle of table rotation at the specified table rate before starting to record torquer current. It is also common practice to obtain average values of torquer current using analog-to-digital conversion and counting total pulses over small time intervals or angles of table rotation.

10.13.3.1.2 *Cogging Method (Acceleration-Insensitive Drift Rate Only)*

Align the servo-table rotational axis north and horizontal within _____ arc seconds. Mount the gyro in the fixture on the servo table with the ORA vertically up within _____ arc minutes and the IA north and parallel to the table rotational axis within _____ arc seconds. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the pickoff output to the table servo loop, properly phased to stabilize the servo table with the gyro. Rotate the servo table about the rotational axis 0.75° from the setup position in a direction opposite the rotation caused by the horizontal component of earth's rate. Insure the gyro is at null and then close the servo loop. When servo table reaches an angle of 0.5 ± _____ ° before the setup position, activate the timer; when the table reaches an angle of 0.5 ± ° beyond the setup position, stop the timer. Capture the gyro and return (cog) the table to the starting position. Repeat this test _____ times.

Capture the gyro, rotate the table 180 ± _____ ° and repeat the above procedure.

10.13.3.1.3 *Multiposition Method*

Align the dividing head with the spindle axis parallel to the horizontal projection of the earth's polar axis within _____ arc seconds. Mount the gyro on the dividing head with the OA north and parallel to the spindle axis within _____ arc seconds. Operate the gyro in the rate-sensing mode (Section 8.2), in accordance with the standard test conditions of Section 9.1. Connect the gyro to the torquer current measurement equipment.

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Orient the gyro IA horizontal and east within _____ arc seconds. Record the torquer current. Rotate the dividing head through 360 °in increments of 45 °. At each position, allow the torquer current to stabilize for _____ minutes and record the torquer current.

Reorient the gyro and the fixture with the SA directed north and parallel to the spindle axis within _____ arc seconds. Repeat the above procedure.

This procedure should be used only if D_{SS}, D_{II}, and D_{OS} are negligible.

10.13.3.1.4 *Vibration (Acceleration-Squared-Sensitive Drift Rate Only)*

Mount the gyro in the fixture to establish the orientation of the gyro axes with respect to the applied vibration as indicated by position 1 in Fig 3. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the test conditions of Section 9.1. Connect the gyro to the torquer current recording equipment.

Determine the average torquer current in this position with no applied vibration. Apply a vibration of _____ *g* peak of _____ Hz as measured at the gyro and determine the difference between the average torquer current with and without vibration. Repeat the procedure at the following frequencies: _____ Hz.

Reorient the gyro to each of the remaining seven positions in Fig 3. At each of these positions, repeat the procedure described in the paragraph above.

Care must be exercised to protect the gyro from extraneous rate inputs. Induced drifts caused by the ambient static and electromagnetic fields produced by the vibration exciter must be considered.

10.13.3.1.5 *Parameter Repeatability*

Repeat the procedure of Section [10.13.3.1.1, 10.13.3.1.2, 10.13.3.1.3, 10.13.3.1.4] times, subjecting the gyro to the conditions of Section _____.

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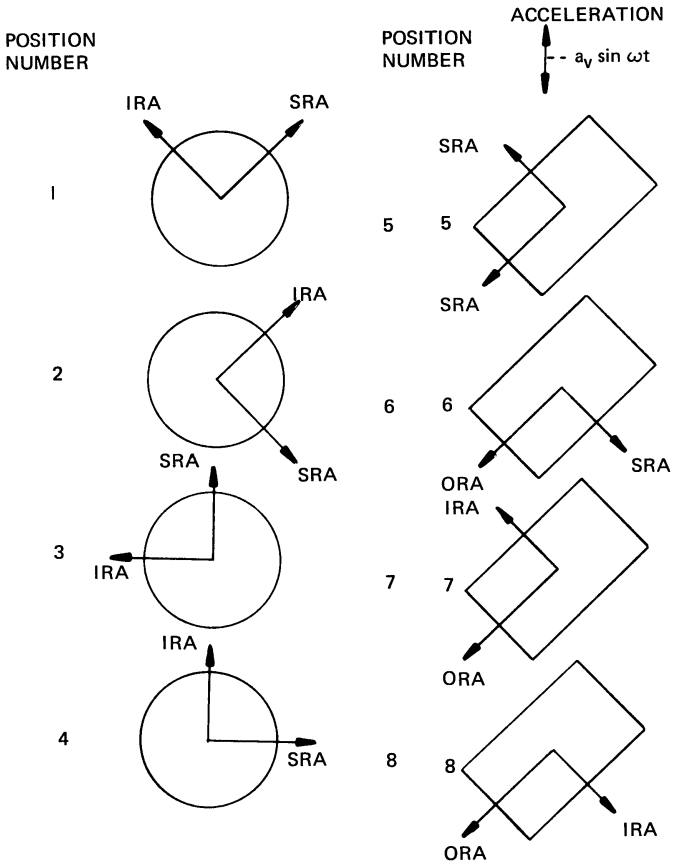


Figure 3—Vibration Drift Test Orientations (Note: axes orientations are parallel of 45° to the acceleration vector within ± _____ °.)

10.13.3.2 *Elastic Restraint Drift Rate Co-efficient*

10.13.3.2.1 *Method 1*

Align the dividing head spindle axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the dividing head so that the gyro IA is parallel to the spindle axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the precision current source to the gyro torquer and connect the pickoff to the pickoff output measurement equipment.

Adjust the torquer current until the pickoff output remains at null. (The output shall not change more than _____ mV/min.) Rotate the dividing head through an angle of _____ ± _____ ° The input motion shall be smooth, continuous, and unidirectional. Record the pickoff output and start the timer. Record the pickoff output when the timer shows 60 seconds have elapsed and calculate the change in the pickoff output during the 60 second period. Return the dividing head to the initial orientation. Repeat the above procedure, except reverse the dividing head rotation.

10.13.3.2.2 *Method 2*

Mount the gyro in a fixture with the IRA north and the ORA vertical within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect a

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voltage source to the rate loop electronics in a manner such that it will add to the pickoff signal. Connect the gyro pickoff to a phase-sensitive voltmeter and the torquer to current-measuring equipment.

Adjust the voltage source until the in-phase pickoff voltage is _____ ± _____ mV as measured on a phase-sensitive voltmeter. Measure the torquer current.

Adjust the voltage source until the pickoff voltage reverses phase and the voltage is _____ ± _____ mV as measured on a phase-sensitive voltmeter. Measure the torquer current.

10.13.3.3 *Gimbal Retardation (Gimbal Friction)*

10.13.3.3.1 *Method 1*

Align the dividing head spindle axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the dividing head so that the ORA is parallel to the spindle axis within _____ arc minutes and the IRA is east within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the current source to the gyro torquer control winding and connect the gyro pickoff to the pickoff output measurement equipment. Adjust the torquer current to hold the gyro pickoff output at null. The output shall not change more than _____ mV/min.

Increase the torquer current _____ μA and measure the elapsed time for the gyro pickoff output to reach _____ mV.

Repeat the above procedure with a decrease in torquer current of the same magnitude.

> The command rate must be chosen small enough so that the gimbal friction is a significant torque on the gimbal. The maximum pickoff output selected must be chosen so that elastic restraint torques do not obscure the friction torque. Therefore, this method is appropriate for those cases where the specification requirement is for near-zero gimbal rotation rates.

10.13.3.3.2 Method 2

Mount the gyro in the fixture on the dividing head with the ORA vertical and up within _____ arc minutes and the IRA east within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1 with the addition of a ramp generator and recorder as shown in Fig 4. Insert a signal from the ramp generator to drive the gimbal from stop-to-stop at a command rate of _____ ° /h. Record the gyro torquer current. Repeat the above procedure with the ORA vertical and down. Repeat again with the IRA up within _____ arc minutes.

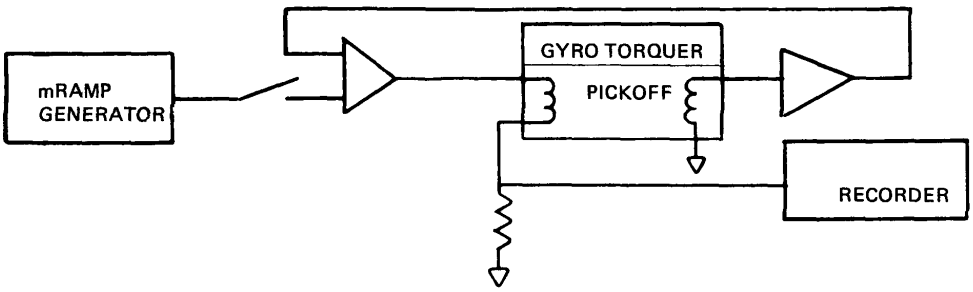


Figure 4—Gimbal Retardation Test Block Diagram

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10.13.3.3.3 Method 3

Orient the tumble table rotational axis parallel to the earth's polar axis within _____ arc seconds. Mount the gyro in the fixture on the table with the OA [north, south] and parallel to the table axis within _____ arc seconds. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the source of current pulses as a parallel input to the torquer. Connect the gyro to the torquer current recording equipment. Operate the tumble table at _____ ± _____ ° /h. Displace the gyro gimbal off null by superimposing a current pulse of _____ ± _____ [mA, _____] for _____ ± _____ seconds on the normal torquer current. Repeat every _____ ± _____ ° of table rotation alternating the polarity of each successive pulse. Continuously record the torquer current while the tumble table rotates through _____ complete revolutions.

> For a more complete knowledge of gimbal retardation characteristics, repeat the aforementioned procedure, reversing the direction of table rotation or the gyro OA orientation, or both.
>
> The amplitude, duration, and timing of the current pulses should be selected to permit observation of settling characteristics.
>
> This test is usually performed in conjunction with the equatorial tumble test in Section _____.

10.13.3.4 *Random Drift Rate*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is [vertical, horizontal, polar] within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the recorder to the torquer current measurement equipment. Start the recorder and record the torquer current for _____ [minutes, hours].

10.13.4 *Test Results*

10.13.4.1 *Acceleration-Insensitive Drift Rate, Acceleration-Sensitive, and Acceleration-Squared-Sensitive Drift Rate Coefficients*

10.13.4.1.1 *Equatorial Tumble Method*

From the test data taken in Section 10.13.3.1.1, compute the drift rate coefficients. The coefficients shall conform to the requirements of Section _____ .

> Specify the data reduction procedure to be used. See Appendix A for suggested data reduction procedure.

10.13.4.1.2 *Cogging Method*

Calculate the average acceleration-insensitive drift rate D_F from the data obtained in Section 10.13.3.1.2 by

$$D_F = \frac{\sum_{i=1}^{N} \left(\frac{1}{T_i} - \omega_H \right)}{N}$$

where T_i is the measured elapsed time in hours, ω_H is the horizontal component of earth rate in degrees per hour, and N is the number of increments. The acceleration-insensitive drift rate shall conform to the requirements of Section _____ .

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10.13.4.1.3 *Multiposition Method*

From the test data obtained in Section 10.13.3.1.3, identify each measurement of torquer current i_{xx} according to Table 1.

Table 1—Torquer Current Designations for Multiposition Drift Rate Test

Angular Position About SA	OA North	SA North
0° (IA east)	i_{11}	i_{21}
45°	i_{12}	i_{22}
90° (IA up)	i_{13}	i_{23}
135°	i_{14}	i_{24}
180° (IA west)	i_{15}	i_{25}
225°	i_{16}	i_{26}
270° (IA down)	i_{17}	i_{27}
315°	i_{18}	i_{28}

Compute the drift coefficients according to Table 2.

Table 2—Computation of Coefficients for Multiposition Drift Rate Test

Coefficients	OA North	SA North
DF	$\frac{K_T(i_{11}+i_{13}+i_{15}+i_{17})}{4}$	$\frac{K_T(i_{21}+i_{23}+i_{25}+i_{27})}{4}$
D_I	$\frac{K_T(i_{13}-i_{17})}{2} - \omega_{EV}$ *	$\frac{K_T(i_{23}-i_{27})}{2} - \omega_{EV}$ *
D_S	$\frac{K_T(i_{11}-i_{15})}{2}$	N/A†
D_O	N/A†	$\frac{K_T(i_{25}-i_{21})}{2}$
D_{IS}	$\frac{K_T(i_{12}+i_{14}+i_{16}+i_{18})}{2}$	N/A†
D_{10}	N/A†	$\frac{K_T(i_{24}+i_{28}+i_{22}+i_{26})}{2}$

* ω_{EV} = Vertical component of the earth's rate.

†N/A = Not applicable.

10.13.4.1.4 *Vibration*

The average torquer current difference determined for each test position of Section 10.13.3.1.4 is Δi corresponding to the ith test position, and D_{xy} is the drift rate coefficient defined in the model equation of the specification format. A_v is the applied acceleration in g peak. The drift rate coefficients are calculated as indicated below using the command rate scale factor K_T determined in Section 10.7.4.1:

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$$D_{IS} = \frac{2K_T(\Delta_1 - \Delta_2)}{A_v^2}$$

$$D_{SS} = \frac{2K_T\Delta_3}{A_v^2}$$

$$D_{II} = \frac{2K_T(\Delta_4)}{A_v^2}$$

$$D_{OS} = \frac{2K_T(\Delta_6 - \Delta_5)}{A_v^2}$$

$$D_{OI} = \frac{2K_T(\Delta_8 - \Delta_7)}{A_v^2}$$

The drift rate coefficients as determined here shall conform to the requirements of Section _____.

10.13.4.2 *Repeatability*

The results shall conform to the requirements of Section _____.

10.13.4.3 *Elastic Restraint Drift Rate Coefficient*

10.13.4.3.1 *Method 1*

Using the value of the gyro scale factor determined in Section 10.12.4.1, the value of the gyro gain determined in Section 10.12.4.2, and the data of Section 10.13.3.2.1, compute the elastic restraint drift rate coefficient for each set of data as:

$$\text{elastic restraint drift rate coefficient} \left(\frac{^\circ/\text{h}}{\text{degree output angle}}\right) = \frac{\text{change in pickoff output (V/min)} \times 60 \text{ (min/h)}}{\text{gyro gain}\left(\frac{\text{degrees output angle}}{\text{degrees input angle}}\right) \times \text{gyro scale factor (V/}^\circ\text{)} \times \text{input angle (degree)}}$$

The result shall conform to the requirement of Section _____.

10.13.4.3.2 *Method 2*

The elastic restraint drift rate coefficient is calculated from data obtained in Section 10.13.3.2.2, the pickoff scale factor determined in Section 10.6.4.1, and the command rate scale factor determined in Section 10.7.4.1 as follows:

$$\text{elastic restraint drift rate coefficient} \left(\frac{^\circ/\text{h}}{\text{degree output angle}}\right) = \frac{\text{change in torquer current} \times \text{command rate scale factor}}{\text{sum of the 2 pickoff voltages} / \text{pickoff scale factor}}$$

The results shall conform to the requirement of Section _____.

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10.13.4.4 *Gimbal Retardation (Gimbal Friction)*

10.13.4.4.1 *Method 1*

The sustained gimbal retardation for each elapsed time is calculated as follows:

$$\frac{E_i - E_p}{T_i \times \mathrm{GSF}}$$

where E_p is the pickoff output prescribed in Section 10.13.3.3.1, and

$E_i = T_i \times \Delta I \times K_T \times \mathrm{GSF}$

where E_i is the calculated gyro pickoff output corresponding to each elapsed time in Section 10.13.3.3.1, and T_i is the measured elapsed time from Section 10.13.3.3.1. ΔI is the increase or decrease in torquer current made during the test procedure in Section 10.13.3.3.1, K_T is the gyro command rate scale factor as determined in Section _____ , GSF is the gyro scale factor as determined in Section _____.

The results shall conform to the requirements of Section _____

10.13.4.4.2 *Method 2*

The peak gimbal retardation is calculated as follows:

peak gimbal retardation = $\Delta I_{max} \times K_T$

where ΔI_{max} is the maximum deviation from the best straight-line fit to that part of the torquer current trace of Section 10.13.3.3.2 that lies within the input angle limits specified in Section _____, and K_T is the command rate scale factor as determined in Section _____.

The results shall conform to the requirements of Section _____.

10.13.4.4.3 *Method 3*

Construct a sine wave S_1 connecting the settled torquer current traces after positive displacement and a second sine wave S_2 connecting the settled torquer current traces after negative displacement.

The sustained gimbal retardation is computed as follows:

sustained gimbal retardation = $K_T \times \Delta I$

where K_T is the command rate scale factor as determined in Section _____, and ΔI is the difference between the average current of S_1 and the average current of S_2.

The result shall conform to the requirements of Section _____.

10.13.4.5 *Random Drift Rate*

10.13.4.5.1 Method 1

Divide the recording of the gyro torquer current obtained in Section 10.13.3.4 into N equal time intervals. Determine the average torquer current for _____ [seconds, minutes] during each interval. The random drift rate (1σ) is then calculated as:

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$$\sigma = \left[\frac{1}{N-1}\sum_{I=1}^{N}(Y_I - \bar{Y})^2\right]^{1/2} \times K_T$$

where Y_i is the average value of the ith sample, is the mean value of the N samples, and K_T is the gyro command rate scale factor as determined in Section 10.7.4.1. The random drift rate shall conform to the requirements of Section _____.

The validity of the best estimate of the standard deviation as a statistical parameter is based upon the assumption that no deterministic functions are present (for example, ramp, sinusoidal, etc). Since the data may contain deterministic functions, an attempt to identify and remove these before computation of o may be appropriate. If this is done, limits for these effects should be specified.

The magnitude of σ may vary considerably with the length of the data-averaging interval. If the data distribution is Gausian, the magnitude of σ will vary as the inverse square root of the averaging interval; therefore, results from tests with different averaging intervals may be compared after normalizing to a common interval. If this is done, the time interval should be specified.

10.13.4.5.2 *Method 2*

From the data obtained in Section 10.13.3.4, calculate the drift rate power spectral density over the bandwidth from _____ to _____ Hz. The gyro random drift rate is calculated as the square root of the integral of the drift rate power spectral density function over the bandwidth from _____ to _____ Hz. The random drift rate shall conform to the requirements of Section _____.

10.14 Output Noise

10.14.1 *Purpose*

The purpose of this test is to measure the gyro output noise.

10.14.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Means of measuring gyro torquer current
2) Means of recording gyro torquer current
3) Gyro torquer supply
4) Means of measuring gyro pickoff output
5) Means of recording gyro pickoff output
6) Means of measuring elapsed time

10.14.3 *Test Setup and Procedure*

10.14.3.1 *Method 1*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is vertical within _____ arc minutes and the gyro IRA is east within _____ arc minutes. Operate the gyro in the rate sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the gyro torquer to the torquer current measurement equipment and record the [rms, peak-to-peak] current.

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10.14.3.2 *Method 2*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is vertical within _____ arc minutes and the gyro IRA is east within _____ arc minutes. Operate the gyro in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the gyro torquer to the torquer current recording equipment. Start the recorder and record the torquer current for _____ [minutes, hours].

> This output noise test technique is similar to that given for random drift rate. It is included since the random drift rate bandwidth specified is commonly limited to lower frequencies than those identified as output noise.

10.14.3.3 *Method 3*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is vertical within _____ arc minutes and the gyro IRA is east within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the precision current source to the gyro torquer and connect the gyro pickoff to the pickoff output measurement equipment. Adjust the torquer current until the pickoff output remains at null. (The average output shall not change more than _____ mV/min.) Record the [rms, peak-to-peak] pickoff output voltage.

10.14.3.4 *Method 4*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is vertical within _____ arc minutes and the gyro IRA is east within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the precision current source to the gyro torquer and connect the gyro pickoff to the pickoff output recording equipment. Adjust the torquer current until the pickoff output remains at null. (The average output shall not change more than _____ mV/min.) Start the recorder and record the gyro pickoff output for [minutes, hours].

10.14.4 *Test Results*

10.14.4.1 *Method 1*

The torquer current measured in Section 10.14.3.1 multiplied by the command rate scale factor as determined in Section 10.7.4.1 is the gyro noise. The gyro noise shall conform to the requirement of Section _____.

10.14.4.2 *Method 2*

From the data obtained in Section 10.14.3.2, calculate the noise power spectral density over the bandwidth from _____ to _____ Hz. The gyro noise is calculated as the square root of the integral of the power spectral density function over the bandwidth from _____ to _____ Hz. The noise as calculated above shall conform to the requirement of Section _____.

10.14.4.3 *Method 3*

The pickoff output voltage measured in Section 10.14.3.3 multiplied by the gyro scale factor determined in Section 10.12.4.1 is the gyro noise. The results shall conform to the requirements of Section _____.

10.14.4.4 *Method 4*

From the data recorded in Section 10.14.3.4, calculate the noise power spectral density over the bandwidth from _____ to _____ Hz. The gyro noise is calculated as the square root of the integral of the power spectral density function over the bandwidth from _____ to _____ Hz. The noise as calculated above shall conform to the requirements of Section _____.

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10.15 Dynamic Response Test Series

10.15.1 *Purpose*

The purpose of this test series is to measure the frequency response, closed-loop step response, and settling time of the gyro.

10.15.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed in this section:

1) Rate table or dividing head
2) Oscillating rate table
3) Means of measuring table rate
4) Means of measuring the gyro output amplitude
5) Means of measuring the gyro output phase with respect to the gyro command rate or the applied rate
6) Gyro torquer supply
7) Gyro capture electronics
8) Means of recording gyro torquer current with respect to time
9) Means of recording gyro pickoff output with respect to time

10.15.3 *Test Setup and Procedure*

10.15.3.1 *Frequency Response*

10.15.3.1.1 *Method I (Applied Rate)*

Align the oscillating rate table axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the table so that the IA is parallel to the table rotational axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the gyro pickoff output to the output measuring equipment and the gyro torquer to the current supply. Adjust the torquer current to maintain the pickoff output at null. Operate the table at a frequency of _____ ± _____ Hz and a rate amplitude of _____ + _____ ° / s. Record the peak-to-peak amplitude of the input rate, the peak-to-peak amplitude of the gyro output, and the phase lag of the gyro output with respect to the rate input. Repeat the above procedure at the following frequencies: _____ Hz.

It may be necessary to select table displacement angles as a function of frequencies to produce an easily discernible signal from the gyro pickoff, but not so high as to cause the float to reach the stops or to exceed the mechanical overload specification. It may be necessary to readjust the torquer current to maintain a symmetrical output.

10.15.3.1.2 *Method 2 (Command Rate)*

Mount gyro on fixture so that the ORA is vertical and the IRA is east within _____ arc minutes. Operate the gyro in the displacement mode (Section 8.1) in accordance with the standard test conditions of Section 9.1. Connect the gyro torquer to a variable oscillator capable of driving the gyro at _____ ° /s peak rate. Connect the gyro pickoff output to the output measuring equipment. Operate the variable oscillator to maintain a peak rate of approximately ° / s at a frequency of _____ ± _____ Hz. Record the peak-to-peak amplitude of the gyro command rate and the

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gyro output; also record the phase lag of the gyro output with respect to the input forcing function. Repeat the above procedure at the following oscillator frequencies: _____ Hz.

> It may be necessary to select oscillator output levels as a function of frequencies to produce an easily discernible signal from the gyro pickoff, but not so high as to cause the float to reach the stops or to exceed the mechanical overload specification. It may also be necessary to provide a torquer bias current to maintain a symmetrical output and limit gyro drift.

10.15.3.2 *Closed-Loop Step Response*

Mount the gyro in the fixture on the dividing head so that the gyro ORA is vertical and the IRA is east within _____ arc minutes. Operate the gym in the rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect a recorder to record the gyro pickoff output and the current through the current source. Connect a high impedance external current source in parallel with the output of the torquer amplifier and adjust the current supply to produce a pickoff output corresponding to the specified input rate. Start the recorder, remove the external current source to produce a step input, and continue to record until the pickoff output has stabilized.

> The rate-sensing mode electronics characteristics will significantly influence the results of this test and consequently the electronics characteristics must be completely specified.

10.15.3.3 *Settling Time*

Mount the gyro in a fixture on a [dividing head, rate table] with the ORA parallel to table rotation axis _____ within arc minutes. Operate the gyro in a rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the gyro to torquer current recording equipment. Orient the table so that gyro ORA is vertical within _____ arc minutes and the IRA is north within _____ arc minutes. Rotate the table approximately _____ ° /s. toward IRA east and allow _____ minutes for the gyro to stabilize.

Start the torquer current recorder and rotate the table back to IRA north within _____ arc minutes at a smooth rate of _____ ± _____ ° /s. Stop the table and mark the recorder chart at the instant the table stops. Continue recording until the torquer current reaches a final value. Repeat the test by returning to north from the opposite direction.

Remount the gyro in the fixture with the IRA axis parallel to table rotational axis within _____ arc minutes. Operate the gyro in a rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1, connecting the gyro to torquer current measuring equipment. Orient the table so that the gyro IRA is vertical within _____ arc minutes and the ORA is north within _____ arc minutes. Rotate the table approximately _____ ° toward the ORA east and allow _____ minutes for the gyro to stabilize. Rotate the table back to ORA north within arc minutes at a smooth rate of + _____ plusmn; _____ ° /s. Stop the table and record torquer current versus time until a final value is reached. Repeat the test by returning to north from the opposite direction.

Remount the gyro in the fixture with the SRA parallel to table rotational axis within _____ arc minutes. Operate the gyro in a rate-sensing mode (Section 8.2) in accordance with the standard test conditions of Section 9.1. Connect the gyro to torquer current recording equipment. Orient the table so that the gyro ORA is vertical within _____ arc minutes and the SRA north within arc minutes. Rotate the table clockwise approximately 180° at a smooth rate of _____ + ° /s. Stop the table and record torquer current versus time until a final value is reached. Repeat the test by rotating counterclockwise to the original position.

> It may be desirable to rotate the gyro about an axis other than vertical.

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10.15.4 *Test Results*

10.15.4.1 *Frequency Responses*

Compute the amplitude and phase response. The results shall conform to the requirements of Section _____.

10.15.4.2 *Closed-Loop Step Response*

The closed-loop step response recorded in Section 10.15.3.2 shall conform to the requirements of Section _____.

10.15.4.3 *Settling Time*

The settling times as recorded in Section 10.15.3.3 shall conform to the requirements of Section _____.

10.16 Angular Acceleration Sensitivity About the Output Axis

10.16.1 *Purpose*

The purpose of this test is to measure the sensitivity of the gyro to angular acceleration about the OA.

10.16.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed here:

1) Oscillating rate table
2) Means of measuring table rate
3) Means of measuring the component of gyro output which is in phase with the table rate
4) Gyro torquer supply

10.16.3 *Test Setup and Procedure*

Align the oscillating rate table axis to within _____ arc minutes of vertical. Mount the gyro in the fixture on the table so that the ORA is parallel to the table rotational axis within _____ arc minutes. Operate the gyro in accordance with the standard test conditions of Section 9.1. Connect the gyro pickoff output to the output measuring equipment and the gyro torquer to the current supply. Adjust the torquer current to maintain the pickoff output at null. Operate the table at a frequency of _____ ± _____ Hz, and an amplitude of _____ ± _____ °. Record the peak-to-peak amplitude of the table rate.

The frequency chosen should not exceed 0.1 of the frequency which is the inverse of the gyro characteristic time as determined in Section 10.12.4. The amplitude of table oscillation should be high enough to produce an easily discernible signal from the gyro pickoff, but not so high as to cause the float to reach the stops. It may be necessary to readjust the torquer current to maintain a symmetrical output excursion during the test.

10.16.4 *Test Results*

Compute the angular acceleration sensitivity about the OA by dividing the peak-to-peak amplitude of the gyro pickoff output by the product of the peak-to-peak amplitude of table rate times the gyro scale factor, as determined in Section 10.12.4.1. The sensitivity of the gyro to angular acceleration about the OA shall conform to the requirements of Section _____.

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10.17 Generated Fields

10.17.1 *Electromagnetic Interference*

The purpose of this test is to measure the electromagnetic interference generated by the gyro.

MIL-STD-462 is a reference commonly used in the United States to describe test procedures and equipment required for this test.

The test should be outlined in the following manner to conform to the format used in the rest of this document:

10.17.1.1 *Purpose*
10.17.1.2 *Test Equipment*
10.17.1.3 *Test Setup and Procedures*
10.17.1.4 *Test Results*

10.17.2 *Magnetic Leakage*

10.17.2.1 *Purpose*

The purpose of this test is to determine the magnetic flux leakage of the gyro.

10.17.2.2 *Test Equipment*

In addition to the standard operating equipment from Section 9.2.2, the following test equipment from Section 9.2.3 is required for this test and shall be listed here:

Magnetic field measuring equipment

10.17.2.3 *Ambient Magnetic Field Test Setup and Procedure*

10.17.2.3.1 *Without Gyro*

Measure and record the magnitude and direction of the ambient magnetic field at the following positions surrounding the gyro test fixture without the gyro present: _____.

10.17.2.3.2 *Gyro Mounted*

Mount the gyro in the test fixture. Repeat the measurements of Section 10.17.2.3.1.

10.17.2.3.3 *Operating*

Operate the gyro in accordance with the standard test conditions of Section 9.1. Repeat the measurements of Section 10.17.2.3.1.

10.17.2.4 *Magnetic Leakage Test Results*

10.17.2.4.1 *Nonoperating*

The magnetic leakage for the nonoperating gyro shall be found by subtracting the measurements of Section 10.17.2.3.1 from the measurement of Section 10.17.2.3.2 for each position specified. The results shall conform to the requirements of Section _____.

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10.17.2.4.2 *Operating*

The magnetic leakage for the operating gyro shall be found by subtracting the measurements of Section 10.17.2.3.1 from the measurements of Section 10.17.2.3.3 for each position specified. The results shall conform to the requirements of Section _____.

Care should be taken in the design of the fixture to minimize its effect on the measurements.

10.18 Environmental Test Series

These tests are to verify that the gyro performs as specified during or after subjection to environments outside of the standard operating conditions, or both, but within the specified environmental limits.

Procedures for most environmental tests are well covered by existing industry, government, and military documents, an example of which is MIL-STD-810, Environmental Testing, Aeronautical and Associated Equipment. Table 3 is intended as a guide in selecting those parameters that are to be tested when the gyro is subjected to a given environment. Criteria used in generating the table include (1) importance of the stability and sensitivity of the parameter in a given environment, and (2) practicability of running the test with existing equipment. Testing should be limited to that required by the application.

The tests should be outlined in the following manner to conform to the format used in the rest of this document:

1. Name of Test
1.1 Purpose
1.2 Test Equipment
1.3 Test Setup and Procedure
1.4 Test Results

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Table 3—Environmental Test Series

ENVIRONMENT / GYRO PARAMETER DESCRIPTION AND PARAGRAPH	4.1 EXAM OF PRODUCT, MECH	4.2 IMPEDANCE TEST	4.3 DIELECTRIC TEST	4.2 INSULATION RESISTANCE	4.3 LEAK TEST	4.4 POLARITY	4.5 TEMPERATURE SENSOR CHARACTERISTICS	4.5 WARM-UP TIME	4.5 OPERATING TEMPERATURE	4.6 PICKOFF SCALE FACTOR & COMP. ERR	4.6 PICKOFF PHASE SHIFT & ELEC NULL	4.7 TORQUER SCALE FACTOR & COMP ERR	4.7 MAXIMUM COMMAND RATE	4.7 CONTINUOUS COMMAND RATE	4.8 ROTOR ROTATION DETECTOR	4.9 RUNUP TIME	4.9 RUNDOWN TIME	4.9 POWER CONSUMPTION	4.10 AXIS ALIGNMENT	4.11 INPUT ANGLE	4.11 LIMIT STOPS	4.12 GYRO SCALE FACTOR	4.12 CHARACTERISTIC TIME	4.13 g^n INSENS., g^n SENS. & g^2 SENS. DRIFT RATE COEFF.	4.13 ELASTIC RESTR. DRIFT RATE COEFF.	4.13 GIMBAL RETARDATION	4.13 RANDOM DRIFT RATE	4.14 OUTPUT NOISE	4.15 FREQUENCY RESPONSE	4.15 CLOSED LOOP STEP RESPONSE	4.15 SETTLING TIME	4.16 ANGULAR ACCELERATION SENSOR ABOUT OA	4.17 GENERATED FIELDS	MONITOR: PICKOFF OUTPUT VOLTAGE	MONITOR: TORQUERCURRENT (CLOSED LOOP)	COMMENTS
1. TEMPERATURE	O N	O N	O N	O N	O N		N	O N	O N	N			N	N		O	O	O				N		N	O		N								For heaterless gyros, performance testing over temperature range will be required.
2. EXCITATION VOLTAGE & FREQ VARIATION		N	N	N			D		D	D	D	D		D	D	D						D		D	D						D				
3. MECHANICAL SHOCK	O N		O N	O N	O N		N		O N		N	N	N		M		N	O N	O N		O N		O N	O N	O N	O N	O N					M		
4. THERMAL SHOCK		D N	D N	D N			N		N	N	N	N	N		N	N	N	N			N		N	N	N										
5. VIBRATION	O N	O N	O N	O N	O N		N	O	O N	O N	O N	O N	O N		O M N	D O N	O N	O N	O N		O N		O N	O N	O N	O N	O N	O N					M	M	It may be desirable to monitor electrical circuits for anomalies.
6. ACCELERATION	O N				N	O	N		O N	N	N	N	N		O M N	D O N	O N	D O N	O N		O N		O N	O N	O N	O N	O N	O N					M	M	Measurement of performance during acceleration may require sled tests.
7. MECH OVERLOAD	O										O	O			O M	O	O	O	O M		O		O	O	O	O	O	O					M		
8. LIFE, STORAGE	N	N	N	N	N		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		N	N	N	N	N	N		N					
8.1 LIFE, OPERATING	O	O	O	O	O		D O	O	D O	D O	D O	D O	O	O	D O	D O	D O	D O	O		O		D O	D O	D O	D O	D O	O		O					
9. FUNGUS	N	N	N	N	N																														
10. HUMIDITY	N	N	N	N	N																														
11. SALT SPRAY	N	N	N	N	N																														
12. ACCOUSTICAL NOISE	O N	O N	O N	O N	O N		N	O	O N	O N	O N	O N	O N		O M N	D O N	O N	O N	O N		O N		O N	O N	O N	O N	O N	O N					M	M	It may be desirable to monitor electrical circuits for anomalies.
13. THERMAL RADIATION								D	D									D						D		D									
14. AIR CURRENTS								D	D									D						D		D									
15. PRESSURE	O					O		D	D		D																								It may be desirable to monitor electrical circuits for anomalies.
16. NUCLEAR RADIATION	N	N	N	N	N		N		N	N	N	N	N	N	N	N	N	N			N		N	N			N	N			N				The hazards of post exposure handling must be considered.
17. MAGNETIC FIELDS										D	D	D			D								D	D	D										
18. ELECTROMAGNETIC FIELDS										D	D	D			D								D	D	D										
19. SAND & DUST	N	N	N	N	N																														
20. SUNSHINE	N	N	N	N	N																														
21. RAIN	N	N	N	N	N																														

D = Gyro parametric test is to be conducted while the gyro is operating or nonoperating as applicable, during the specified environment.
O = Gyro is to be operated during the specified environment and the parametric test performed before and after.
N = Gyro is to be nonoperating during the specified environment, and the parametric test performed before and after.
S = Special test is recommended as described under "Comments."
M = Monitor output indicated in table; when monitor output is the requirement, further clarification is necessary as to how output variation is to be judged.

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Annex A

Rate-Integrating Gyro Design Features

(Informative)

(These appendixes are not a part of IEEE Std 517-1974, Specification Format Guide and Test Procedure for Single-Degree-of-Freedom Rate-Integrating Gyros.)

Pickoff	Spin Motor	Damping Type
(1) Variable Reluctance (microsyn)	(1) AC Synchronous Hysteresis (3-phase, 2-phase)	(1) Fluid
(2) Moving Coil	(2) AC Induction (squirrel cage rotor) (3-phase, 2-phase)	(2) Magnetic (eddy current)
(3) Other (optical, capacitance, shorted-turn, potentiometer)	(3) DC (with governor)	
Damping Regulation	**Torquer**	**Rotor Rotation Detector**
(1) Self-Compensated	(1) Variable Reluctance	(1) Pulse
(2) Temperature Controlled	(2) DC Permanent Magnet	(2) Near Sinusoidal
(3) Uncompensated	(3) Other (shorted-turn, electrodynamic, Kelvin balance, ac induction)	
Gimbal Suspension	**Rotor Suspension**	
(1) Electromagnetic Centering	(1) Ball Bearing	
(2) Electrostatic Centering	(2) Hydrodynamic Gas Bearing	
(3) Ball Bearing		
(4) Jewel and Pivot		
(5) Flexure or Torsion Pivot (ligament)		
(6) Hydrostatic Bearing		
(7) Partial or Full Floatation (in conjunction with the above)		

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Annex B Equatorial Tumble Test Suggested Data Reduction Procedure (Informative)

B.1 Introduction

Suggested data reduction procedures for equatorial tumble test are described in this appendix. Various combinations of gyro orientations with respect to the turntable are employed dependent upon the assumed model equation and the information desired.

B.2 Model Equation

The model equation of a single-degree-of-freedom rate-integrating gyro is defined as a series that mathematically relates the output of a gyro to the several inputs to the gyro. The complete assumed model equation appears in Section 6.3 of this guide. The steady-state form of the model equation for the single-degree-of-freedom rate-integrating gyro when each term has the dimensions of angular velocity is

$$
\begin{aligned}
&-K_T i \\
&\quad = \omega_I \text{ (rate, in inertial space, about the IA)} \\
&\qquad + D_F \text{ (acceleration-insensitive drift rate)} \\
&\qquad + D_I a_I + D_O a_O + D_S a_S \text{ (acceleration-sensitive drift rate)} \\
&\qquad + D_{II} a_I^2 + D_{SS} a_S^2 + D_{IS} a_I a_S + D_{IO} a_I a_O \\
&\qquad + D_{OS} a_O a_S \text{ (acceleration-squared-sensitive drift rate)}
\end{aligned}
\qquad \text{(B-1)}
$$

where i is the torquer current required to maintain the gimbal at null, and the gyro elastic restraint drift rate for small gimbal displacement about the output axis is assumed to be negligible.

The acceleration and acceleration-squared terms of B-1 will have correct signs if the positive direction of the gravity vector is defined as an apparent upward acceleration (g) acting on the gyro (apparent because it is not the second time derivative of a position vector.)

Symbols used in the model equation are defined as follows:

i = torquer current
K_T = command rate scale factor

The polarity of K_T should be consistent with the polarity convention of Fig 1, Sections 3.3.23.1 and 3.3.23.3 of the specification. The preferred sign convention for K_T is (+). A positive $K_T i$ and an ω_I represent rates of like sign (that is, a negative i will be required to restore the gimbal to null in the presence of a positive ω_I).

For command rates that are generated by torquer inputs other than the first power of i (that is, variable reluctance torquers, pulse torquing, etc), the term $K_T i$ should be replaced with a command rate term consistent with the torquer or technique used and with the sign convention established.

a_I = acceleration along the IA (input axis)
a_O = acceleration along the OA (output axis)
a_S = acceleration along the SA (spin axis)
D_F = drift rate that is insensitive to acceleration
$D_I a_I$ = drift rate attributable to acceleration along the IA, where D_I is a drift rate coefficient
$D_O a_O$ = drift rate attributable to acceleration along the OA, where D_O is a drift rate coefficient

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$D_S a_S$	= drift rate attributable to acceleration along the SA, where D_S is a drift rate coefficient
$D_{II} a_I^2$	= drift rate attributable to the square of acceleration along the IA, where D_{II} is a drift rate c0oefficient.
$D_{SS} a_S^2$	= drift rate attributable to the square of acceleration along the SA, where D_{SS} is a drift rate coefficient
$D_{IO} a_I a_O$	drift rate attributable to the product of accelerations along the IA and OA, where D_{IO} is a drift rate coefficient
$D_{IS} a_I a_S$	= drift rate attributable to the product of accelerations along the IA and SA, where D_{IS} is a drift rate coefficient
$D_{OS} a_O a_S$	= drift rate attributable to the product of accelerations along the OA and SA, where D_{OS} is a drift rate coefficient
ω_I	= angular velocity, with respect to inertial space, of the gyro case about the IA

B.3 Gyro and Turntable Orientation

For the equatorial tumble test the table rotational axis is aligned parallel to the earth's polar axis. The gyro is aligned with its OA at an angle A_R with respect to the table rotational axis. The table is rotated and data taking starts when the IA is horizontal and directed east (see Fig B.1).

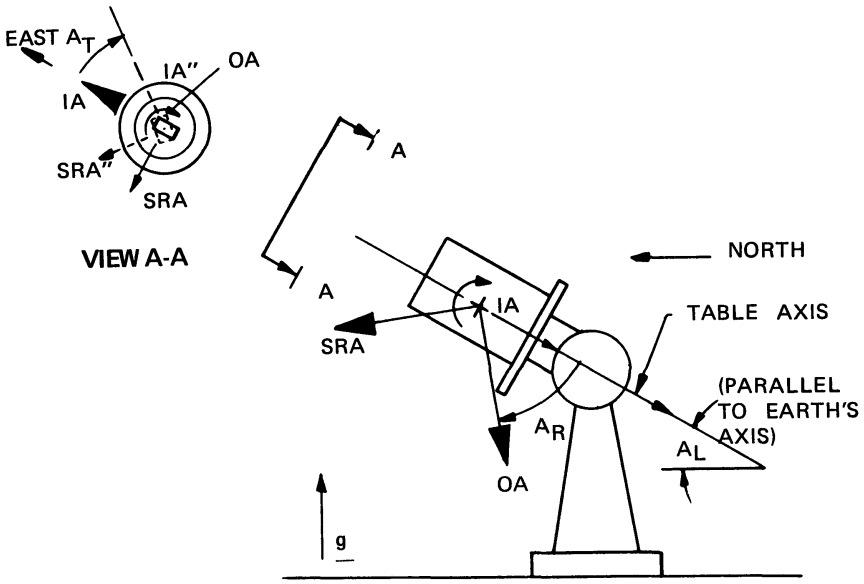


Figure B.1—Gyro and Turntable Orientation for Equatorial Tumble Testing

The components of acceleration acting along each of the gyro axes are

$$a_I = g \cos A_L \sin A_T$$

$$a_O = -g(\sin A_L \cos A_R + \cos A_L \sin A_R \cdot \cos A_T)$$

$$a_S = g(\sin A_L \sin A_R - \cos A_L \cos A_R \cdot \cos A_T)$$

where

A_L	= latitude angle
A_T	= table angle

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A_R = orientation of gyro OA measured with respect to the turntable axis

The above angles are measured in the direction shown in Fig B.1:

1) For OA south and parallel to the earth's polar axis, $A_R = 0°$
2) For SRA (spin reference axis) north and parallel to the earth's polar axis, $A_R = 90°$
3) For OA north and parallel to the earth's polar axis, $A_R = 180°$
4) For SRA south and parallel to the earth's polar axis, $A_R = 270°$

At each reference angle A_R, measurements of the torquer current are made at equally spaced values of table angle A_T over a complete revolution. The number of such table angles at which the torquer current is measured is based on statistical consideration but, in general, should be at least equal to twice the number of model equation coefficients to be determined.

B.4 Clockwise and Counterclockwise Rotations

When data from both clockwise and counterclockwise rotations are combined, the effect of a misalignment of the IA with respect to the plane perpendicular to the table axis is removed. The magnitude of this misalignment angle in radians is computed by

$$\text{Misalignment angle (rad)} = \frac{\Delta\omega_I}{2\omega_T} \qquad \text{(B-2)}$$

where $\Delta\omega_I$ is the difference in the observed drift rate for clockwise and counterclockwise rotations and ω_T is the rate at which the table is rotated.

An additional advantage of both clockwise and counterclockwise rotation is that the number of degrees of freedom is doubled. This can serve to reduce the standard error of the coefficient.

B.5 Coefficient Determination and Evaluation

B.5.1 Method 1, Direct Technique

B.5.1.1 *Matrix Notation for Model Equation*

In matrix notation, B-1 may be written

$$Y = AD \qquad \text{(B-3)}$$

where Y is an $n\times1$ column vector of the n observed values of $-K_T i$ for each orientation, A is an $n\times9$ matrix of the functions of acceleration components along the gyro axis, and D is a 9×1 column vector of the drift coefficients. ω_I in B-1 is zero since the IA remains perpendicular to the earth's polar axis throughout the test. The functions of acceleration corresponding to the acceleration-sensitive and acceleration-squared-sensitive terms are shown in Table B.1 for each of the four orientations.

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Table B.1—Acceleration Terms Used in Model Equation

	$A_R = 0°$	$A_R = 90°$	$A_R = 180°$	$A_R = 270°$
a_I	$g \cos A_L \sin A_T$	$g \cos A_L \sin A_T$	$g \cos A_L \sin A_T$	$g \cos A_L \sin A_T$
a_o	$-g \sin A_L$	$-g \cos A_L \cos A_T$	$g \sin A_L$	$g \cos A_L \cos A_T$
a_S	$-g \cos A_L \cos A_T$	$g \sin A_L$	$g \cos A_L \cos A_T$	$-g \sin A_L$
a_I^2	$g^2/2 \cos^2 A_T(1 - \cos 2 A_T)$	$g^2/2 \cos^2 A_L (1 - \cos 2 A_T)$	$g^2/2 \cos^2 A_L(1 - \cos 2 A_T)$	$g^2/2 \cos^2 A_L (1 - \cos 2 A_T)$
a_S^2	$g^2/2 \cos^2 A_L (1 + \cos 2 A_T)$	$g^2 \sin^2 A_L$	$g^2/2 \cos^2 A_L (1 + \cos 2 A_T)$	$g^2 \sin^2 A_L$
$a_I a_O$	$-g^2 \sin A_L \cos A_L \sin A_T$	$-g^2/2 \cos^2 A_L \sin 2 A_T$	$g^2 \sin A_L \cos A_L \sin A_T$	$g^2/2 \cos^2 A_L \sin 2 A_T$
$a_I a_S$	$-g^2/2 \cos^2 A_L \sin 2 A_T$	$-g^2 \sin A_L \cos A_L \sin A_L$	$g^2/2 \cos^2 A_L \sin 2 A_T$	$-g^2 \sin A_L \cos A_L \sin A_T$
$a_O a_S$	$g^2 \sin A_L \cos A_L \cos A_T$	$-g^2 \sin A_L \cos A_L \cos A_T$	$g^2 \sin A_L \cos A_L \cos A_T$	$-g^2 \sin A_L \cos A_L \cos A_T$

B.5.1.2 *Least Squares Fit*

A fit of the assumed performance model to the data is made using the method of least squares. It is easily mechanized with matrices by multiplying both sides of B-3 by the transpose of A:

$$A^T Y = A^T A D \qquad \text{(B-4)}$$

This expression is a representation of the "normal" equations that are a result of the least squares criterion. The matrix $A^T A$ is a 9×9 square matrix that can be inverted, provided it is nonsingular. The solution for D is

$$D = [A^T A]^{-1} A^T Y \qquad \text{(B-5)}$$

For a two orientation test the matrices are combined as follows:

$$[A_1^T Y_1 + A_2^T Y_2] = [A_1^T A_1 + A_2^T A_2] \qquad \text{(B-6)}$$

and the solution for the drift coefficients is

$$D = [A_1^T A_1 + A_2^T A_2]^{-1} [A_1^T Y_1 + A_2^T Y_2] \qquad \text{(B-7)}$$

Similarly three orientations may be combined.

B.5.1.3 *Selection of Orientations*

When data from only one test orientation is used, the $[A^T A]$ matrix is singular and a solution for all coefficients is not possible. If a combination of two orientations 180° apart is used, the matrix is invertable provided either D_{II} or D_{SS} is assumed insignificant and is deleted from the model. If any three orientations are combined, the matrix is nonsingular and a solution for all nine coefficients is possible. Table B.2 summarizes the coefficients obtainable from each possible combination of orientations.

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Table B.2—Gyro Orientation and Recoverable Coefficients

Orientations Used A_R	Recoverable Coefficients	Assumptions Necessary
0, 180°	$D_F, D_I, D_O, D_S, \left\{ \begin{matrix} D_{II} \\ \text{or} \\ D_{SS} \end{matrix} \right\}, D_{IS}, D_{IO}, D_{OS}$	$\left\{ \begin{matrix} D_{SS} \\ \text{or} \\ D_{II} \end{matrix} \right\} = 0$
90°, 270°	$D_F, D_I, D_O, D_S, D_{II}, D_{IS}, D_{IO}, D_{OS}$	$D_{SS} = 0$
0, 90°, 180°	All	None
90°, 180°, 270°	All	None
0, 90°, 180°, 270°	All	None

If, for example, D_{SS} is assumed insignificant and is deleted from the model for the two orientation tests, but is in fact present, the resulting solution for D_F is in error by an amount equal to $(\sin^2 A_L)\, D_{SS}$.

B.5.1.4 *Standard Deviation of Residuals*

In a least squares fit the sum of the squares of the residuals is minimized and the mean value of the residuals is zero. The residual for a given table angle is

$$\begin{aligned} r = & -K_T i - D_F - D_I a_I - D_O a_O - D_S a_S - D_{II} a_I^2 \\ & - D_{SS} a_S^2 - D_{IO} a_I a_O - D_{IS} a_I a_S - D_{OS} a_O a_S \\ & - \omega_I \end{aligned} \qquad \text{(B-8)}$$

The best estimate of the standard deviation of the residuals of the fit is

$$\sigma_r = \sqrt{\frac{\sum_{j=1}^{N} r_i^2}{N-9}} \qquad \text{(B-9)}$$

where N is the total number of torquer current samples. $N = 3n$ for a three orientation test. The 9 represents the number of coefficients in the model.

B.5.1.5 *Test for Significance of Coefficient*

In order to establish some degree of confidence in the estimate of a coefficient the standard error of that coefficient is computed. For the m^{th} coefficient D_m,

$$\sigma_m = \sigma_r \sqrt{b_{mm}} \qquad \text{(B-10)}$$

where σ_m is the standard error of D_m, b_{mm} is the element on the main diagonal of the inverted least squares matrix in the m^{th} row and m^{th} column.

To determine if D_m is significantly different from zero a t test may be performed. If

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$$\left|\frac{D_m}{\sigma_m}\right| \geq t \qquad \text{(B-11)}$$

the coefficient is significant. The value of t depends upon the desired confidence interval and the number of degrees of freedom. Usually a 95 percent confidence interval is used. The number of degrees of freedom is equal to *N*-9 or *N*-8. For a two orientation test with 36 angular positions of the table for each orientation, the number of degrees of freedom is

$2(36) - 8 = 64$

and the value of *t* is 1.96.

Failure of the *t* test by a coefficient does not necessarily indicate that the error is not present in the gyro but, rather, may indicate any or of the following:

1) Incomplete model
2) Measurement error large compared to coefficient magnitude
3) Additional data are required to reduce the effect of random noise

NOTE — The magnitude of σ_m may be decreased to some extent by increasing the number of degrees of freedom (that is, by increasing the number of data points in the fit).

B.5.2 Method 2, Fourier Analysis Technique

This alternate method is presented for coefficient determination only. If statistical evaluation is desired, Method 1 is recommended.

A Fourier analysis is performed on the data obtained in each orientation. The values of the drift coefficients are determined by combining the Fourier coefficients.

Using data obtained by the test procedure, Section _____, compute the Fourier coefficients through the second harmonic.

Orientation 1

1) OA south and parallel to the earth's polar axis, $A_R = 0°$. $A_T = 0°$ when IA is east
2) Determine Fourier coefficients α_{01}, α_{11}, α_{21}, β_{11}, and β_{21}, from the relation
$-K_T i_2 = \alpha_{01}, + \alpha_{11}, \sin A_T + \alpha_{21}, \sin 2A_T + \beta_{11} \cos A_T + \beta_{21} \cos 2A_T$

Orientation 2

1) OA north and parallel to the earth's polar axis, $A_R = 180°$. $A_T = 0°$ when IA is east
2) Determine Fourier coefficients α_{02}, α_{12}, α_{22}, β_{12}, and β_{22} from the relation
$-K_T i_2 = \alpha_{02} + \alpha_{12} \sin A_T + \alpha_{22} \sin 2A_T + \beta_{12} \cos A_T + \beta_{22} \cos 2A_T$

Orientation 3

1) SRA north and parallel to the earth's polar axis, $A_R = 90°$. $A_T = 0°$ when IA is horizontal and east
2) Determine Fourier coefficients α_{03}, α_{13}, α_{23}, β_{13}, and β_{23} from the relation
$-K_T i_3 = \alpha_{03} + \alpha_{13} \sin A_T + \alpha_{23} \sin 2A_T + \beta_{13} \cos A_T + \beta_{23} \cos 2A_T$

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As indicated in Table B.2 of this appendix, the recoverable drift coefficients depend on the positions used. The Fourier coefficients for Orientations I and 2 can be used to determine drift coefficients as follows:

$$D_{\mathrm{I}} = \frac{\alpha_{11} + \alpha_{12}}{2g \cos A_{\mathrm{L}}} \quad \text{(B-12)}$$

$$D_{\mathrm{O}} = \frac{\alpha_{02} - \alpha_{01}}{2g \sin A_{\mathrm{L}}} \quad \text{(B-13)}$$

$$D_{\mathrm{S}} = \frac{\beta_{12} - \beta_{11}}{2g \cos A_{\mathrm{L}}} \quad \text{(B-14)}$$

$$D_{\mathrm{IO}} = \frac{\alpha_{12} - \alpha_{11}}{g^2 \sin 2A_{\mathrm{L}}} \quad \text{(B-15)}$$

$$D_{\mathrm{OS}} = \frac{\beta_{11} + \beta_{12}}{g^2 \sin 2A_{\mathrm{L}}} \quad \text{(B-16)}$$

$$D_{\mathrm{IS}} = \frac{\alpha_{22} - \alpha_{21}}{g^2 \cos^2 A_{\mathrm{L}}} \quad \text{(B-17)}$$

$$D_{\mathrm{F}} = \frac{\alpha_{01} + \alpha_{02} - g^2 \cos^2 A_{\mathrm{L}}(D_{\mathrm{II}} + D_{\mathrm{SS}})}{2} \quad \text{(B-18)}$$

D_{F} can only be evaluated if assumptions are made or if data from an additional orientation are available. Table B.3 shows some of the possible assumptions and resulting coefficient solutions.

D_{II}, D_{F}, and D_{SS} can be determined by including the data from orientation 3:

$$D_{\mathrm{II}} = \frac{-2\beta_{23}}{g^2 \cos^2 A_{\mathrm{L}}} \quad \text{(B-19)}$$

$$D_{\mathrm{SS}} = \frac{2(\beta_{22} - \beta_{23})}{g^2 \cos^2 A_{\mathrm{L}}} \quad \text{(B-20)}$$

$$D_{\mathrm{F}} = \frac{\alpha_{01} + \alpha_{02}}{2} - \beta_{22} + 2\beta_{23} \quad \text{(B-21)}$$

The Fourier coefficients are related to the drift coefficients in the following manner:

$$\alpha_{01} = D_{\mathrm{F}} + \frac{g^2}{2} \cos^2 A_{\mathrm{L}}(D_{\mathrm{II}} + D_{\mathrm{SS}}) - D_{\mathrm{O}}\, g \sin A_{\mathrm{L}}$$

$$\alpha_{11} = D_{\mathrm{I}}\, g \cos A_{\mathrm{L}} - D_{\mathrm{IO}}\, g^2 \sin A_{\mathrm{L}} \cos A_{\mathrm{L}}$$

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$$\alpha_{21} = -D_{IS}\frac{g^2}{2}\cos^2 A_L$$

$$\beta_{11} = D_S\, g \cos A_L + D_{OS}\, g^2 \sin A_L \cos A_L$$

$$\beta_{21} = (D_{SS} - D_{II})\frac{g^2}{2}\cos^2 A_L$$

Table B.3—Drift Coefficient Solutions Using Fourier Analysis

Drift Coefficients \ Assumption	$D_{II} = 0$	$D_{SS} = 0$	D_F Is Known
D_F	$-\beta_{21} + \frac{\alpha_{01} + \alpha_{02}}{2}$	$\beta_{21} + \frac{\alpha_{01} + \alpha_{02}}{2}$	D_F
D_{II}	0	$-\frac{2\beta_{21}}{g^2 \cos^2 A_L}$	$\frac{\alpha_{01} + \alpha_{02} - 2D_F - 2\beta_{21}}{2g^2 \cos^2 A_L}$
D_{SS}	$-\frac{\beta_{21} + \beta_{22}}{g^2 \cos^2 A_L}$	0	$\frac{\alpha_{01} + \alpha_{02} - 2D_F + 2\beta_{21}}{2g^2 \cos^2 A_L}$

Orientation 2: $A_R = 180°$

$$\alpha_{02} = D_F + (D_{II} + D_{SS})\frac{g^2}{2}\cos^2 A_L + D_O\, g \sin A_L$$

$$\alpha_{12} = D_I\, g \cos A_L + D_{IO}\, g^2 \sin A_L \cos A_L$$

$$\alpha_{22} = D_{IS}\frac{g^2}{2}\cos^2 A_L$$

$$\beta_{12} = D_S\, g \cos A_L + D_{OS}\, g^2 \sin A_L \cos A_L$$

$$\beta_{22} = (D_{SS} - D_{II})\frac{g^2}{2}\cos^2 A_L$$

Orientation 3: $A_R = 90°$

$$\alpha_{03} = D_F + D_{II}\, g^2 \cos^2 A_L + D_S\, g \sin A_L + D_{SS}\, g^2 \sin^2 A_L$$

$$\alpha_{13} = D_I\, g \cos A_L + D_{IS}\, g^2 \sin A_L \cos A_L$$

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$$\alpha_{23} = -D_{IO}\frac{g^2}{2}\cos^2 A_L$$

$$\beta_{13} = -D_O\, g \cos A_L + D_{OS}\, g^2 \sin A_L \cos A_L$$

$$\beta_{23} = -D_{II}\frac{g^2}{2}\cos^2 A_L$$

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