

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**

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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.

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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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:

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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*

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 1965¹
- 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

- 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 $\pm$ _____ [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 $\pm$ _____ [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

_____ $\pm$ _____ V/[rad, °] input angle.

3.3.3 Gyro Gain

H/C, _____ $\pm$ _____ [rad/rad, °/°].

3.3.4 Characteristic Time

J/C, _____ $\pm$ _____ seconds.

3.3.5 Operating Temperature

_____ $\pm$ _____ [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.

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**

_____ $\pm$ _____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA].

For a variable reluctance torquer the scale factor shall be _____ $\pm$ _____ [(rad/s)/mA², (rad/h)/mA², ($^{\circ}$ /s)/mA², ($^{\circ}$ /h)/mA²].

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, $^{\circ}$ /s, $^{\circ}$ /h].

3.3.9.4 Maximum Command Rate

Minimum: _____ [rad/s, rad/h, $^{\circ}$ /s, $^{\circ}$ /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

_____ $\pm$ _____ V (at rated speed).

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

_____ $\pm$ _____ μ s from _____ percent to _____ percent peak amplitude.

3.3.10.5 Total Output

_____ $\pm$ _____ 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**

_____ $\pm$ _____ 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.

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

$D_F, 0 \pm$ _____ [rad/h, °/h].

3.3.14.2 Repeatability

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

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) $D_I, 0 \pm$ _____ [(rad/h)/g, (°/h)/g]
- 2) $D_S, 0 \pm$ _____ [(rad/h)/g, (°/h)/g]
- 3) $D_O, 0 \pm$ _____ [(rad/h)/g, (°/h)/g]

3.3.15.2 Repeatability

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

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

$0 \pm$ _____ [(rad/h)/g², (°/h)/g²].

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.

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.

3.3.21 Angular Acceleration Sensitivity About the Output Axis

_____ [(rad/h)/(rad/s²), (°/h)/(rad/s²)] 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·cm²/s.

3.3.22.2 Rotor Speed

_____ r/min.

3.3.22.3 Gimbal Moment of Inertia

_____ g·cm².

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.

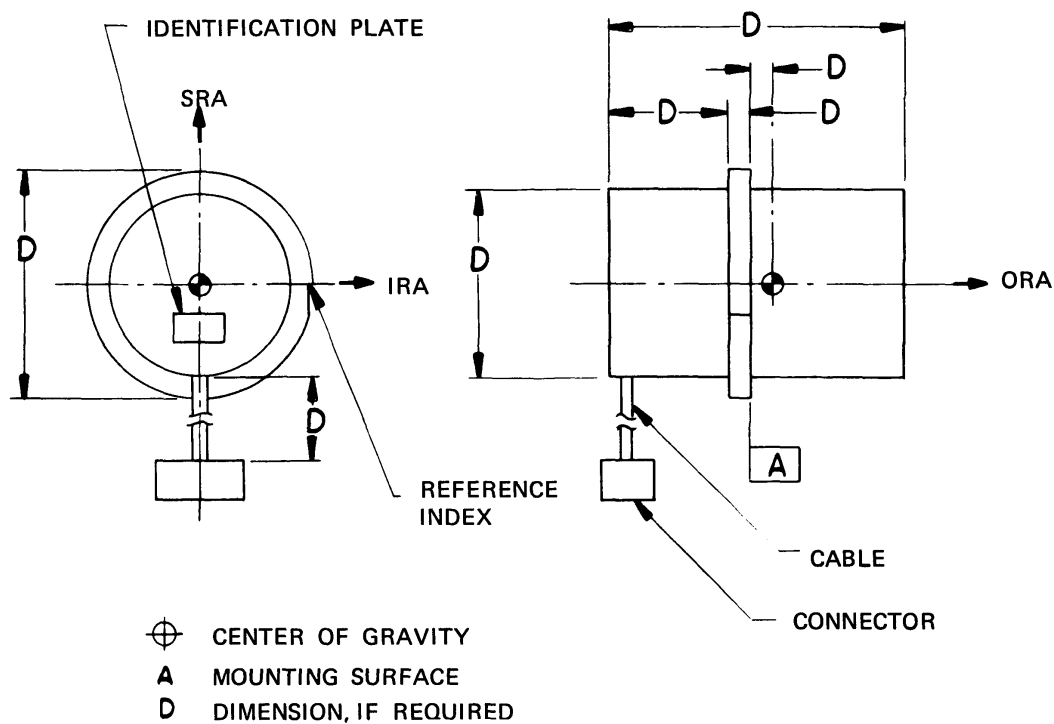
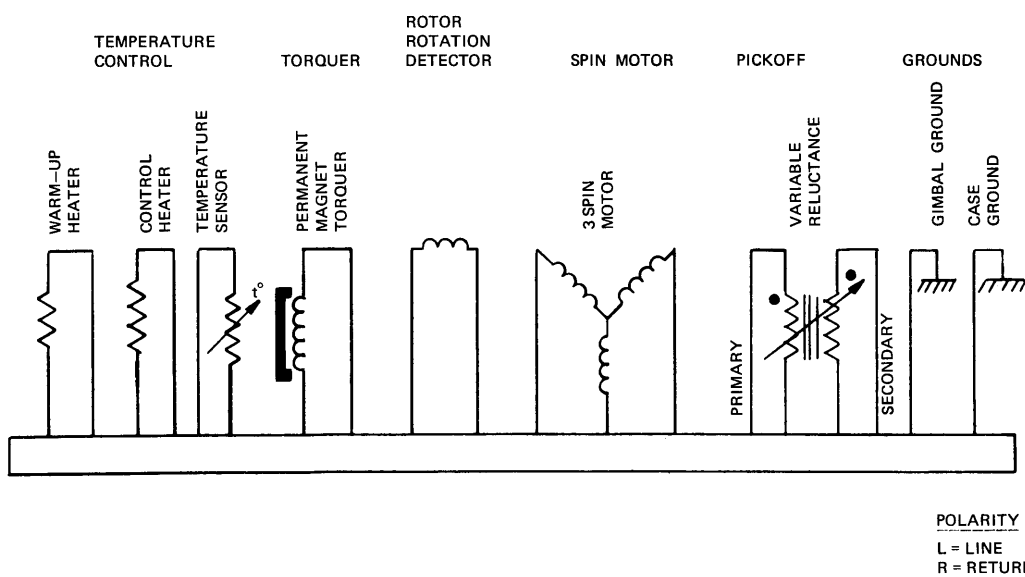


Figure 1—Typical Rate-Integrating Gyro Outline Drawing

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

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*

_____ $\pm$ _____ [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 _____ $\pm$ _____ torr and a gyro temperature of _____ $\pm$ _____ °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.

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: _____ $\pm$ _____ V [dc, ac, _____ phase, _____ $\pm$ _____ 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 _____ $\pm$ _____ Ω [$+$, $-j$] _____ $\pm$ _____ Ω when measured at _____ Hz and at [operating temperature, _____ $\pm$ _____ $^{\circ}$ C].

- 6) Phase splitting capacitor: _____ $\pm$ _____ μF
- 7) Overvoltage: _____ percent for _____ seconds maximum

3.5.2.2 Pickoff

- 1) Excitation: _____ $\pm$ _____ [V, mA] [dc, ac, _____ Hz $\pm$ _____ 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 _____ $\pm$ _____ Ω [+, -] j _____ $\pm$ _____ Ω when measured at _____ Hz and at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$]
- 4) Secondary impedance: The impedance of the secondary as measured with the primary [open circuited, short circuited] shall be _____ $\pm$ _____ Ω [+, -] j _____ $\pm$ _____ Ω , when measured at _____ Hz and at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$]
- 5) Load impedance: _____ $\pm$ _____ Ω [+, -] j _____ $\pm$ _____ Ω
- 6) Carrier phase shift, primary to secondary voltage: _____ $\pm$ _____ $^{\circ}$, when connected to the specified load

3.5.2.3 Temperature Control

The resistance of the temperature sensor(s) shall be _____ $\pm$ _____ 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, $^{\circ}\text{C}$] at _____ mA. The resistance scale factor of the temperature sensor(s) shall be [+, -] _____ $\pm$ _____ $\Omega/^{\circ}\text{C}$, at operating temperature.

- 1) Warm-up heater excitation: _____ $\pm$ _____ V [dc, ac, _____ $\pm$ _____ Hz]
- 2) Warm-up heater power: _____ W maximum
- 3) Control heater excitation: _____ $\pm$ _____ V [dc, ac, _____ $\pm$ _____ 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: _____ $\pm$ _____ $\Omega + j$ _____ $\pm$ _____ Ω at _____ Hz at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$].

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

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: _____ $\pm$ _____ V [dc, ac, _____ $\pm$ _____ Hz]
- 2) Current: _____ $\pm$ _____ mA
- 3) Input impedance: _____ $\pm$ _____ Ω [+, -]/j _____ $\pm$ _____ Ω when measured at Hz _____ and at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$]

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 _____ $\text{M}\Omega$ measured at _____ $\pm$ _____ V dc applied for _____ $\pm$ _____ seconds.

3.5.4 Dielectric Strength

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

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.

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 , $^\circ/\text{s}$] 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 , $^\circ/\text{s}^2$] have been applied about the _____ [axis, axes] for _____ seconds a total of _____ times per direction.

3.6.4.5 Temperature

_____ $^\circ\text{C}$ to _____ $^\circ\text{C}$.

3.6.4.6 Thermal Shock

_____ $^\circ\text{C}$ to _____ $^\circ\text{C}$ 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: _____.

3.6.4.8 Ambient Air Pressure

_____ [Pa,² torr, inHg, lb/in²] to _____ [Pa, torr, inHg, lb/in²].

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 _____ $\pm$ _____.

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 _____ /cm² 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.

3.6.4.17 Sand and Dust

_____ [g/m³, g/ft³] at a velocity of _____ $\pm$ _____ [m/s, ft/min]; exposure time: _____. Relative humidity not to exceed _____ percent.

Specify particle size, shape, and chemical composition.

3.6.4.18 Sunshine

_____ $\pm$ _____ [W/m², w/ft²] of wavelength _____ to _____ meters; exposure time: _____

Describe distribution of power density versus wavelength.

3.6.4.19 Rain

_____ $\pm$ _____ [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.

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