29 January 1968

Materiel Test Procedure 5-2-514
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

MISSILEBORNE GYROSCOPE TESTS

1. OBJECTIVE

The objective of the procedures outlined in this Materiel Test Procedure (MTP) is to detect limitations and other characteristics which will determine the applicability of a gyroscopic component to a given use.

2. BACKGROUND

Gyroscopes are used in missiles to produce a stable and predictable flight path by providing angular error data for in-flight course correction. Adverse gyroscope characteristics may deter the gyroscope performance.

Some of these adverse characteristics are variation of drift rate, changes of transfer function of the gimbal stabilization loop, Gimbal bearing friction, mass unbalance, and changes in electrical noise. This MTP relates tests to discover if these adverse characteristics exist.

3. REQUIRED EQUIPMENT

a. Multiohmmeter or Wheatstone Bridge, as applicable
b. Five-hundred Volt D-C Megger
c. High Potential (Hy-Pot) Meter (1000 volts minimum)
d. Ammeters as required
e. Resistance Bridge as required
f. Shallcross Test Set No. 6100 or equivalent
g. Vacuum Tube Voltmeter (VTVM) as required
h. LVM-5 Voltmeter or equivalent
i. S.I.E. Model R-1 Voltmeter or equivalent
j. Potentiometer
k. Instrumentation to Measure Table Level (horizontal plane)
l. Recorders, as required

    1) Two channel
    2) Single channel

m. Test Fixtures as required:

    1) Right angled fixture for mounting to an indexing head
    2) Fixture for mounting to a Scorsby table

n. Demodulating Equipment
o. Test Equipment

    1) Indexing head

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  2) Scorsby table
  3) Swing table (G accelerator)
  4) Oscillatory rate simulating table (Micro-Gee Model 10-C or equivalent)
  5) Dividing head
  6) Equatorial turn-table (Sidereal rate table)

p. Synchro
q. Oscilloscope
r. Berkeley Counter or equivalent

4. REFERENCES

A. AF Manual 52-31, Guided Missiles Fundamentals, Dept. of the Air Force, Washington, D. C., 20 September 1957.
B. Lees, Sidney, Air, Space, and Instruments, McGraw-Hill Book Company, Inc., 1963
C. Van Nostrand, D., International Dictionary of Physics and Electronics, D. Van Nostrand Co., Inc., New York
D. Roberts, Harold A., Durkee, Roger P., and Borer, Walter M., A Guide for Testing the Miniature Integrating Gyro (MIC) GG 49, Minneapolis-Honeywell Aero Document U-ED 9788, January 1958
E. Volk, J. A., Gyroscopes, The Greenleaf Mfg. Co., St. Louis, Missouri, 1957

5. SCOPE

5.1 SUMMARY

This procedure describes tests to be performed on the various type gyros, to ensure that they are within their specifications, as follows:

a. For All Gyros:

  1) Phasing (rotor, pickoff or signal generator)
  2) Rotor characteristics

b. For Free or Two Degree of Freedom Gyros:

  1) For free gyro a-c pickoff gyros:

    a) Gimbal freedom tests
    b) Gimbal caging provisions
    c) Average sensitivity or scale factor
    d) Linearity
    e) Slip ring test
    f) Alignment of gyro axis
    g) Gyro drift test

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2) For free gyro, d-c pickoff of the displacement or amount type, preset gyros:

    a) Potentiometer tests
    b) Threshold sensitivity
    c) Sensitivity resolution
    d) Null region
    e) Potentiometer tap location

c. For Rate or Single Degree of Freedom Gyros:

1) For common type rate gyros having a d-c potentiometer pickoff

    a) Static balance
    b) Dynamic balance
    c) Threshold sensitivity
    d) Alternating component
    e) Range hysteresis error
    f) Potentiometer resolution
    g) Sensitivity resolution
    h) Calibration, repeatability and linearity
    i) Friction
    j) Frequency response
    k) Case leakage
    l) Width of potentiometer wiper

2) For integrating rate gyros of the floated gimbal, pickoff type

    a) Gyro transfer function
    b) Gimbal freedom rate
    c) Null repeatability
    d) Fixed torque
    e) Elastic restraint
    f) Unbalance, gimbal and mass
    g) Axes alignment
    h) Random drift (cogging)

5.2 LIMITATIONS

Due to the variety of gyroscopic sensing elements and testing equipment, this MTP is restricted to general test methods; however, the procedures may be adapted, as necessary, to accommodate specific units.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Pre-Test Conditions

Ensure that personnel, cognizant of both the test item and test equipment are available.

6.1.2 Arrival Inspection Tests

The test item shall be subject to the following upon its arrival at the test site:

a. Adequacy of packaging - Visually inspect the test item and record the following:

1) Binding deficiencies such as broken straps, locks, etc.
2) Packaging material deficiencies such as cuts, tears, breaks, etc.

b. Visually inspect the test item and record the following:

1) Defects in material
2) Poor workmanship
3) Compliance of test item configuration with its associated drawings and military specifications
4) Adequacy of markings for identification

6.1.3 Resistance and Insulation

a. Measure the point resistance values at accessible test points and compare the results with values calculated from a study. of associated schematics or from applicable MTP's.

NOTE: 1. Connecting plug pins often provide convenient points (sometimes the only points) from which tests can be made).

2. Multiohmmeters and/or ohmmeters of the Wheatstone bridge type are used to find the resistance values.

b. Determine the insulation between isolated circuits and the assembly case, and between independent circuits using a five hundred volt d-c megger.

c. Perform dielectric tests between independent circuits and between circuits and case using a high potential (hy-pot) meter.

6.2 TEST CONDUCT

6.2.1 Procedures Common to All Gyros

See Appendix A for a general discussion of gyros and rotors.

6.2.1.1 Phasing

6.2.1.1.1 Rotor Rotation - For a test site in the northern hemisphere:

a. Mount the test item in the center of a rate of turn table so that the spin reference angle (SRA) and the rate turn table axis are vertical and parallel to within 30 arc minutes.

b. Electrically connect and monitor the gyro in accordance with its related schematics.

c. Start and operate the rate table at a rate of approximately 100 degrees/sec. in a counter clockwise (CCW) direction as viewed from above.

d. Record the direction of spin of the gyro spin rotor using the following criteria:

1) For a spin rotor rotating in a CCW direction with both the rate table and spin rotor rotating in the same direction, and having their respective axes both vertical and parallel, there would be little or no force about the gyro input axes (IA), therefore the output signal from the gyro's output axis (OA) or pickoff will decrease slightly or remain near zero.
2) For a spin rotor rotating in a clockwise (CW) direction: The respective axes are now approximately parallel, as such there will now be a slight force about the IA causing an OA gimbal precession which will increase with time. The OA gimbal will continue to process until a gimbal limit stop is reached at which point the output signal from the pickoff will be maximum.

e. For a test site in the southern hemisphere perform steps a through d with the rate turn table rotating in a CW direction.

6.2.1.1.2 Pickoff or Signal Generator Phasing - Determine and record the rate and direction of gimbal precession as indicated in paragraph 5 of Appendix A using the rotor rotation direction of paragraph 6.2.1.1.1.

6.2.1.1.3 Signal Generator or Pickoff Characteristics (for a-c inductive pickoff synchro) - Determine the instantaneous polarity between the primary and secondary windings to verify pickoff or signal generator phasing (paragraph 6.2.1.1.2) as follows:

a. Instrument the synchro as indicated in Figure 1.
b. Place SW 1 in position 1.
c. Energize the primary and record the voltage as E_1.
d. Place SW 1 to position 2 and record the voltage as E_2.

NOTE: For correct operation E_2 must be less than E_1.

e. Repeat steps a through d with the temporary jumper connected to lead 5 to verify phasing of the second half of the secondary.

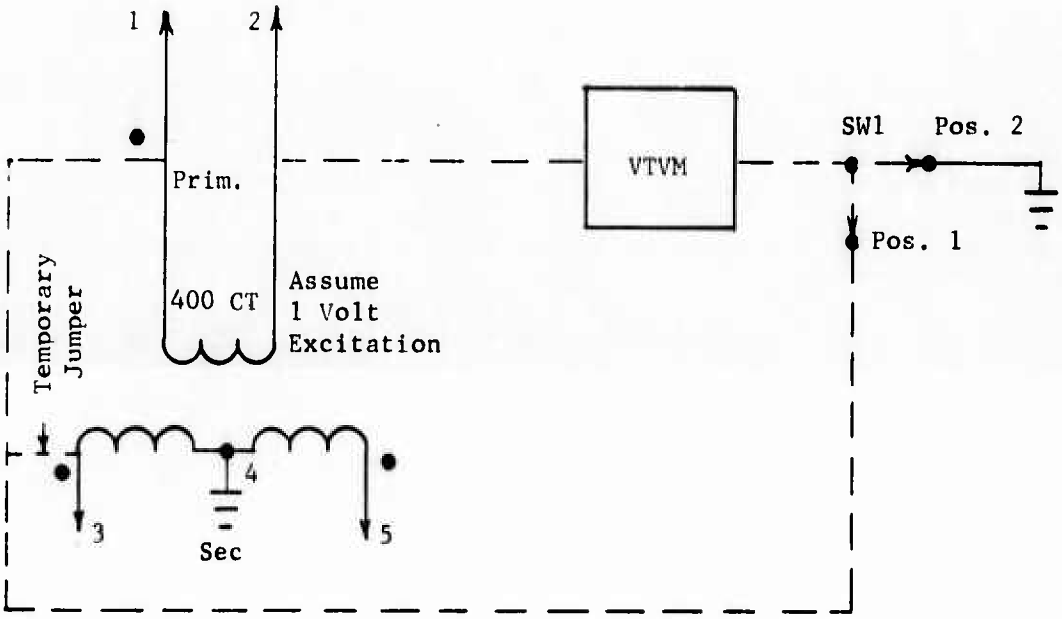


Figure 1. Determining Polarity Relationships

6.2.1.2 Rotor Starting Time, Rotor Starting Current and Running Current, and Rotor Friction or Coast Down Time

Perform the following:

a. Preparation for test:

1) Connect a low ohmage, high voltage resistor (R) (20 ohms or less) in series with one phase or lead of the rotor supply circuit. Record the resistance value.

NOTE: If the rotor is 3-phase, a similar resistor should be connected in each phase to avoid unbalancing the voltage.

2) Connect a VTVM (No. 1) across one of the resistors.
3) Connect a VTVM (No. 2) across the line voltage input to the gyro rotor.

NOTE: Connect the VTVM to the load side of the resistor(s).

4) Apply voltage to the gyro rotor and adjust it to the test items specified gyro rotor.
5) Parallel the two VTVM's with a two channel recorder which has been accurately calibrated for the anticipated voltages (VTVM Nos. 1 and 2).

b. Rotor Starting time and currents:

1) Simultaneously close the switch starting the rotor and the switch starting the tape recorder.
2) Observe the reading of VTVM No. 1 until stabilization is obtained and then stop the recorder.
3) Mark the tape recorder tape speed and voltage calibration information on the tape and determine and record the time required for the rotor voltage to reach stabilization (rotor starting time).
4) Record the initial voltage value on the tape for the determination of rotor starting current.
5) Record the stabilized voltage value on the tape for the determination of rotor running current.

c. Rotor Friction or coast down time

1) Pull about six inches of the recorder tape across the mandrel by hand and reduce the tape speed setting, as required, to accommodate the expected coast down time (may require several minutes).
2) Simultaneously start the tape recorder and open the switch which supplies the rotor power.
3) Observe VTVM No. 2 until the voltage decreases to zero. Stop the recorder.
4) Mark the tape recorder tape speed on the tape and determine and record the time required for the rotor to coast down.

6.2.2 Tests Peculiar to Free, or Two Degree of Freedom Gyros

See Appendix B for a discussion of these gyros.

6.2.2.1 Tests Peculiar to Free Gyro, A-C Pickoff

6.2.2.1.1 Gimbal Freedom - Assume that the gyro has 360 and 85 degrees freedom about its outer and inner gimbals, respectively. If the gyro under test has different limits of freedom, the following test can be tailored to fit the case.

a. Attach the gyro to an indexing head so that the outer gimbal axis is vertical and the inner gimbal axis is horizontal with the indexing head level in both planes.

b. Energize the gyro and let the unit warm up completely and record the outer gimbal output voltage.

c. Tilt the indexing head 85 degrees, minus 5 and plus 0 degrees, about the gyro's inner gimbal axis and maintain this angle through step d.

d. Rotate the test gyro slowly and smoothly through 360 degrees about the rotational axis of the indexing head. The rotation should be accomplished in approximately one-and-a-half minutes.

e. Restore the indexing head to its original position and record the difference in the outer gimbals output voltage in relation to the voltage of step b.

f. Rotate the indexing head 180 degrees about the rotational axis and record the outer gimbals output voltage.

g. Tilt the indexing head 85 degrees, minus 5 and plus 0 degrees, about the gyro's inner gimbal axis and maintain this angle through step h.

h. Rotate the test gyro slowly and smoothly through 360 degrees about the rotational axis of the indexing head. The rotation should be accomplished in approximately one-and-a-half minutes.

NOTE: Rotate the unit in the opposite direction of step d.

i. Restore the indexing head to its original position and record the difference in the outer gimbals output voltage in relation to the voltage of step f.

6.2.2.1.2 Gimbal Caging Provisions - Determine the following:

a. Continuity of caging circuitry:

1) Verify circuit continuity by closing the caged and uncaged switches, respectively, and establishing continuity between the proper pins as indicated on the test item's schematic.

b. Caging accuracy and backlash:

1) Operate the gyro through the caged-uncaged cycle a minimum of three times, with the gyro energized and running and measure and record the outer and inner gimbal output voltages each time the gyro is caged.

2) Mount the test item on a Scorsby table and cage the unit after energizing and running it.
3) Operate the Scorsby table in yaw, roll, and pitch at approximately ± 7.5 degrees at an oscillating frequency of approximately 5 cycles per minute and perform the following:

   a) Record the voltage output of both the inner and outer gimbals.
   b) Observe the outputs on an oscilloscope and determine and record if the null point of the individual outputs is passed through.

c. Caging and uncaging time:

1) Mount the gyro on an indexing head, so that the outer gimbal axis is vertical and the inner gimbal axis is horizontal, with the indexing head level in both planes, and instrument the gyro with a counting device (Berkeley Counter) wired to stop counting when the item becomes caged/uncaged.
2) Energize the gyro and let the unit warm up and become stabilized.
3) Displace the gyro 180 degrees about the outer gimbal axis and 85 degrees about the inner axis.
4) Apply the caging signal and start the counter simultaneously.

NOTE: 1. The caging signal shall be applied for no longer than necessary.

2. Caging should take place within 15 seconds or as specified in the test item's specifications for "worst case" time.

5) Record the time required to effect caging.
6) Apply the uncaging signal and start the counter simultaneously and record the following:

   a) Time required to effect uncaging

   NOTE: Uncaging shall be effected within 0.1 seconds unless otherwise specified.

   b) Pickoff null output voltage to determine if it is within specifications.

7) Apply the caging signal and start the counter simultaneously and perform the following:

   a) Apply the uncage signal prior to completion of caging.
   b) Record the time required for caging.

d. Uncage displacement

1) Operate the energized, stabilized gyro from caged to uncaged a minimum of three times.
2) Record the difference in synchro voltage readings between caged and uncaged attitudes.

NOTE: The differences in caged and uncaged voltage will be the uncage displacement and should not exceed the specified limits, usually about 0.5 degrees.

e. Cage-uncage current and indication current:

1) Install ammeters in the caging and indicating circuits.
2) During operation of the cage and uncage circuitry, record the

current in the cage-uncage circuitry and each of the indicating circuits.

NOTE: Currents should not exceed specified limits; usually 800 milliamps for the cage-uncage circuitry and 15 milliamps for the indicating circuits.

6.2.2.1.3 Outer Gimbal Average Sensitivity or Scale Factor (SF) - Perform the following:

a. Open circuit test

1) Mount the gyro on the indexing head with the spin axis of the gyro perpendicular to the rotational axis of the head, and the indexing head table horizontal and level.
2) Connect a load resistor to the outer gimbal pickoff and place a voltmeter across the resistor. Record the resistor value (approximately 10K).
3) With the gyro warmed-up, running in a suitable manner, and caged record the voltage across the load resistance.
4) Uncage the gyro and rotate the table slowly through one degree clockwise and record the voltage across the load resistor.
5) Cage the gyro.
6) Uncage the gyro and rotate the table slowly through two degrees clockwise and record the voltage across the load resistance.
7) Cage the gyro.
8) Repeat steps 6 and 7 with the table rotated 3, 4, 5, and six degrees.
9) Repeat steps 3 through 8 with the table rotated counter-clockwise.

b. Closed circuit test

1) Mount the gyro on the indexing head as indicated in step a.1.
2) Connect an external synchro to the test gyro synchro stator and the load resistor of step a.2 across the rotor of the external scope.
3) Repeat steps a.3 through a.9.
4) Connect an oscilloscope across the rotor leads of the external scope.
5) Mount a dial, capable of being accurately read to better than 0.05 degrees, on the shaft of the external synchro.
6) Uncage the test gyro and rotate the table 5 degrees clockwise.
7) Turn the shaft of the external gyro to obtain a null reading on the oscilloscope and record the dial reading. Cage the test gyro.
8) Uncage the test gyro and rotate the table 10 degrees clockwise.
9) Repeat step 7.
10) Repeat steps 8 and 9 with the table rotated up to 50 degrees clockwise in 5 degrees increments.

6.2.2.1.4 Inner Gimbal Average Sensitivity or Scale Factor (SF) - Perform the following:

Repeat the procedures of paragraph 6.2.2.1.3 with the inner gimbal axis oriented vertically.

6.2.2.1.5 Slip Ring Test - Determine and record a total lack of evidence of intermittent synchro output voltages during the conduct of paragraphs 6.2.2.1.1 through 6.2.2.1.4.

6.2.2.1.6 Alignment of Axis of Gyro - Determine the following:

NOTE: Construct a right angled fixture that will accurately and securely hold the test gyro so that a flat surface of the fixture can be bolted to an indexing head.

a. Spin axis alignment with reference to the gyro's mounting surface as follows:

1) Mount the test gyro on an indexing head so that the plane of the gyro, as determined by the mounting provisions, shall be perpendicular to the rotational axis of the indexing head, and the spin axis of the gyro shall be vertical and parallel to the rotational axis of the indexing head.
2) Connect a voltmeter to measure the inner gimbal output using load resistor of paragraph 6.2.2.1.3.a.2.
3) Energize, fully warmup, and cage the test gyro.
4) Uncage the gyro and slowly turn the indexing head 360 degrees both clockwise and counterclockwise and monitor the inner gimbal output.
5) Record the peak clockwise and counterclockwise voltages obtained.
6) Record if the null point was passed through.

b. Outer gimbal perpendicularity to the inner gimbal as follows:

1) Mount the test gyro on the indexing head so that the outer gimbal axis is perpendicular to the rotational axis of the indexing head and the gyro can be tilted about its inner gimbal axis.

NOTE: The inner gimbal axis and the tilt axis of the indexing head shall be parallel to within 1 arc minute.

2) Connect a voltmeter to measure the outer gimbal output using the load resistor of paragraph 6.2.2.1.3 a.2.
3) Energize, fully warmup, and cage the test gyro.
4) Uncage the test unit and record the outer gimbal output.
5) Tilt the test gyro about its inner gimbal axis 75° to 90°. Record the degrees of tilt.
6) Record the outer gimbal output.

c. Outer gimbal nonorthogonality with the case:

1) Prepare the test gyro as indicated in step b.1 through b.3 above.
2) Determine the value of E-1 as follows:

   a) Uncage the test unit and record its outer gimbal output.
   b) Tilt the indexing head 80 degrees about the inner gimbal.

   NOTE: Perform this tilt with extreme caution, being careful not to jar or move the gyro suddenly.

   c) Rotate the indexing head 180 degrees clockwise about its rotational axis.
   d) Restore the test gyro to its original position tiltwise and record the outer gimbal output.

3) Determine the value of E-2 as follows:

   a) Orient the gyro on the indexing head with the outer gimbal axis vertical.
   b) With the gyro running in a stable condition uncage it and record the output gimbals output.
   c) Rotate the indexing head 180 degrees counterclockwise about its rotational axis and record the outer gimbals output.

6.2.2.1.7 Gyro Drift Test - Perform the following:

NOTE: 1. Six gyro positions generally are used for calibration and testing purposes. These six positions henceafter shall be referred to as the "six standard positions of test":

	Position 1	Position 2	Position 3
Outer Gimbal Axis	Vertical	East-West	North-South
Spin Axis	North-South	North-South	Vertical
Inner Gimbal Axis	East-West	Vertical	East-West
Top	Up	East	South

Position 4 - Rotate 180 degrees about the inner gimbal axis from Position 1.
Position 5 - Rotate 180 degrees about the outer gimbal axis from Position 2.
Position 6 - Rotate 180 degrees about the outer gimbal axis from Position 3.

NOTE: 2. Drift should be measured using the tandem synchro method, and the drift during the test may be defined as the difference in null shift position of the external synchro prior to and after the drift test.

Prepare a test fixture capable of holding the test gyro so that it can be mounted on a Scorsby table in any and all of the six standard positions of test.

a. Static drift

1) Mount the test gyro/fixture on a Scorsby table in standard position No. 1 and attach an external synchro, loaded with the resistor of paragraph 6.2.2.1.3.b2 in tandem with the test gyro.
2) Energize, warmup and cage the test gyro in standard position No. 1
3) Null the external synchro and record its shaft position.
4) Uncage the test gyro and allow it to drift for exactly one minute.
5) Renull the external synchro and record its shaft position.
6) Repeat steps 1 through 5 for the remaining 5 standard positions.

b. Dynamic drift

1) Mount the test gyro/fixture on a Scorsby table, in standard position No. 1 and attach an external synchro loaded with the resistor of paragraph 6.2.2.1.3.b.2, in tandem with the test gyro.
2) Use a level to ensure that the Scorsby table is horizontal in plane and level.
3) Energize, warmup and operate the test gyro in the caged position until it is running stable. Measure and record the voltage across the load resistor of the external synchro at null and the external synchro shift position.
4) Uncage the test gyro and tilt adjust the Scorsby table for 7.5 degrees ± 0.5 degrees and start the Scorsby in motion in a clockwise direction at a rate of 5 cycles per minute. Continue the Scorsby rotation for five minutes.
5) Stop the Scorsby table and erect it to horizontal using the level of step 2.
6) Rotate the external synchro shaft to obtain a null. Record the external synchro shaft position.
7) Repeat steps 1 through 5 for the remaining 5 standard positions.

6.2.2.2 Tests Peculiar to Free Gyro, D-C Pickoff, of the Displacement or Amount Type having a Preset Feature

6.2.2.2.1 Potentiometer Tests - Assume the following conditions: A directional gyro with the spin reference axis (SRA) horizontal athwartship and sensitive to yaw and roll; there is only one output potentiometer (pot) and it is affixed between the outer gimbal and the gyro case; the pot-winding is closed upon itself and is connected as shown in Figure 2.

NOTE: Figure 2 is common to this type of gyro. If there is a pot on the inner gimbal assume that it is similarly connected.

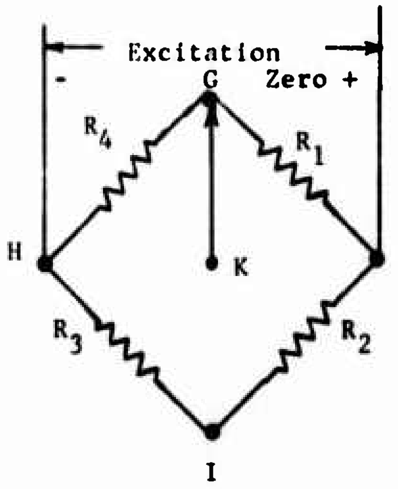


Figure 2. Gyro Potentiometer

a. Resistance values

1) Leave the gyro completely deenergized in the test locality for a sufficient length of time to allow all its parts to attain ambient temperature. Record the ambient room temperature.
2) Mount the gyro on the table in such a way as to prevent its movement during the test.

NOTE: The location of the potentiometer wiper is not important, but its position should not be changed while resistance measurements are being made.

3) Using a Shallcross Test Set No. 6100 or equivalent perform the following:

    a) Measure and record the resistance across H and J.
    b) Measure and record the resistance across G and I.

b. Potentiometer resolution (number of wire turns (wires) contained in the potentiometer), number of wires per degree and resistance per wire

1) Mount the gyro on an indexing head so that the SRA will be truly horizontal and the indexing head is on zero setting.

NOTE: This is a true belly-down attitude when a directional gyro has been assumed.

2) Connect a VTVM to measure the potentiometer output across pins "G" and "K" on the test items test panel.
3) Energize the gyro and preset the potentiometer wiper to zero or "G" or zero tap on the potentiometer.
4) Ensure that the potentiometer wiper is on "G", not "I", as follows:

    a) Operate the preset motor in a clockwise direction and note if the potentiometer output meter reads positive. If a positive reading is not obtained the wiper is on the false zero "I", instead of "G", and:
    b) Continue to drive the preset motor until the output meter reads zero. This should be "G", the true zero. Verify the position by driving the preset motor in a clockwise direction and noting a positive voltage output.

5) Accurately set the potentiometer wiper on zero by monitoring the pot output with the VTVM set on the MV scale.
6) Connect a Sanborn or Brush recorder to pins "G" and "K" of the gyro test panel. Allow the recorder to warmup and adjust the stylus to approximately the center of the chart.
7) Adjust the recorder amplitude so that the crossing of one wire by the potentiometer wiper will cause a stylus deflection of two to three millimeters as follows:

    a) Uncage the gyro by means of the uncage switch on the test circuitry panel. Observe that the uncage light lights.
    b) Take a physical position back of the indexing head so that the eyes are looking into a direction analagous to standing at the rear of a missile, looking in the direction of flight with the missile belly down.
    c) Start the recorder on slow speed and rotate the indexing head in small increments. Note that when the potentiometer wiper moves from one side to another the stylus moves in steps horizontally across the chart.
    d) Adjust the recorder gain until these steps have an amplitude of 2 to 3 millimeters.
    e) After calibration, restore the indexing head to zero and cage the gyro.

8) Set the recorder stylus to the extreme left side of the chart on slow speed (25 mm/sec or less) and uncage the gyro.
9) Rotate the indexing head in a counterclockwise direction slowly, as in step 7c, so that each wire swept by the wiper will be shown on the chart as a step. Record the polarity of the gyro output signal which activates the recorder stylus.

NOTE: The polarity should be positive.

10) Continue the slow counterclockwise rotation until the gyro has been through 360 mechanical degrees.

NOTE: 1. At times, the stylus will reach the full travel of the chart; when this occurs, reset the stylus to the left side of the chart.

2. The gyro output will build up positively until approximately 90 degrees is reached. The amplitude then will begin to decrease but will still be positive. Near 180 degrees the amplitude will decrease to zero, then increase and begin an alternation or half cycle in a negative direction.

11) When 360 degrees have been reached, cage the gyro and deenergize it by turning off the test panel. Tear off the chart, identify it descriptively, and mark it Chart No. 1.

c. Width of potentiometer wiper contact surface: Access to inside parts of the potentiometer is not normally possible in these gyros. Therefore, unless a spare gyro is available for dismantling, this test cannot be conducted. Information pertaining to the width of the potentiometer contact surface is available from the manufacturer as a "statement of fact". When such a statement of fact is obtained from a manufacturer, together with a certificate of compliance, the information obtained may be accepted as true. For those cases in which a dismantled potentiometer is available, determine the width of the wiper contact surface as follows:

1) Connect a resistance bridge across pins "K" and "C" and precess to gyro to obtain zero resistance (this will place the wiper at "G").
2) Change the bridge connections from "G" and "K" to "G" and "H", and record the resistance and designate the resistance as JR_1.
3) Process the gyro in a counterclockwise direction until the wiper is somewhere between "G" and "H" and measure and record the resistance as JR_2.

6.2.2.2.2 Threshold Sensitivity - Perform the following:

a. Mount and energize the test gyro on the indexing head as described in paragraph 6.2.2.2.1.b steps 1 through 5.

b. Uncage the gyro. If the VTVM monitored output reading changes, reduce it to zero or minimum by rotating the indexing head slightly.

c. With the voltage output at minimum note the indexing head reading, then rotate the indexing head slightly until the VTVM indicates an output change. Read the indexing head reading and record the rotation in degrees necessary to produce an output voltage change.

d. Restore the indexing head to its original position (maximum potentiometer output).

e. Repeat steps c and d with the indexing head rotated in the opposite direction.

f. Repeat steps c through e until 3 readings in each direction have been obtained.

6.2.2.2.3 Sensitivity Resolution - Perform the following:

a. Mount and energize the test gyro on the indexing head as described in paragraph 6.2.2.2.1.b steps 1 through 5 and uncage the gyro.

b. Rotate the gyro to a 10 degree clockwise (CW) angle of roll and accurately:

1) Record the setting of the indexing head.
2) Note the reading of the VTVM.

c. Slowly rotate the indexing head in a CW direction until a change is noted on the VTVM. Accurately record the index head setting.

d. Return the indexing head to its position prior to step c.

e. Repeat steps b through d for a CW angle of 20 degrees.

f. Repeat steps b through c with gyro roll angle and indexing head in a counter-clockwise rotation.

NOTE: If a large discrepancy exists between the four displaced indexing head readings, consult with a responsible engineer before proceeding further.

6.2.2.2.4 Null Region - The null region and width of potentiometer tap "G" are considered one and the same thing. Determine the null region and the width of all taps, as follows:

a. Mount and energize the test gyro on the indexing head as described in paragraph 6.2.2.2.1.b steps 1 through 5 and uncage the gyro.

b. Rotate the gyro slightly CCW so that the VTVM indicates a small output.

c. Rotate the gyro CW until the VTVM reads zero or minimum, and record the indexing head reading.

d. Rotate the gyro CW until the VTVM indicates a small output and record the indexing head reading.

e. Rotate the gyro 180 degrees so that the wiper is on the false zero point (Tap I) and repeat the procedures of steps b through d.

f. Repeat steps b through d to determine the width of taps "H" and "J".

6.2.2.2.5 Potentiometer Taps, Location - Perform the following:

a. Mount the test gyro on an indexing head so that the SRA will be truly horizontal and the indexing head is on zero setting.

b. Connect a VTVM, or recorder, to measure the potentiometer output across pins "G" and "K" on the test items test panel.

c. Energize the gyro and preset the potentiometer wiper to zero (pin "G").

d. Rotate the indexing head and gyro in a CW direction. The potentiometer movement is from zero toward 90 degrees (tap J) and yields a voltage of positive polarity.

e. Determine the width of tap J as follows:

1) Record the indexing head reading when the maximum positive voltage is reached (the point at which tap J is reached).
2) Continue to rotate the indexing head and gyro in a CW direction and record the indexing head reading when the voltage starts to decrease (the point at which tap J is left).

f. Continue to rotate the indexing head and gyro in a CW direction and determine the location and width of taps I, H, and G using the technique of step e and the following voltages:

1) Tap I: Zero voltage to negative voltage
2) Tap H: Maximum negative voltage to start of less negative voltage
3) Tap G: Zero voltage to positive voltage

NOTE: Unless otherwise specified the taps should be 90 degrees apart.

6.2.3 Tests Peculiar to Rate or Single Degree of Freedom Gyros

See Appendix C for a discussion of these gyros.

6.2.3.1 Tests Peculiar to Common Type Rate Gyros Having a D-C Potentiometer Pickoff

6.2.3.1.1 Static Balance or Null - An unbalanced gyro will respond to linear acceleration; therefore balance tests should be performed first, since many of the other procedures subject the gyro to linear acceleration.

a. Mount the gyro on a G Accelerator (Swing table) so that the sensitive axis (IA) is at right angles to the axis of table rotation, and the SRA is parallel to the table rotation axis.

NOTE: The gyro should be mounted on the table so that the center of the wheel will be coincident with the radius of gyration. Mount a counter balancing weight on the swing table diametrically opposite to the gyro. The radius of gyration may be any convenient known distance.

b. Connect the gyro with and record, when applicable, the correct voltages and record the output voltage.

NOTE: The output should be near zero or one half the potentiometer excitation voltage, depending on the test item under test.

6.2.3.1.2 Dynamic Balance - With the test item mounted and excited as described in paragraph 6.2.3.1.1, perform the following:

a. Start the swing table and bring it up to a speed of 225 rpm and record the gyro output as dynamic balance position 1.

NOTE: For a gyration radius of 7 inches, a swing table speed produces an acceleration of approximately 10g when rotating at 225 rpm.

b. Reorient the gyro on the swing table by 90 degrees maintaining the conditions of paragraph 6.2.3.1.2 and the same radius of gyration used in step a.

c. Repeat step a and record the gyro output as dynamic balance position 2.

d. Reorient the gyro on the swing table by turning the unit in an upright position on the same radius of gyration used in step a.

NOTE: This orientation still leaves the sensitive axis (IA) at right angles to the axis of rotation.

e. Repeat step a and record the gyro output as the dynamic balance position 3.

6.2.3.1.3 Threshold Sensitivity - Sensitivity tests include measurements of the test item's hysteresis characteristics, its calibration and its linearity as well as its threshold sensitivity. These tests are described in paragraphs 6.2.3.1.4 and 6.2.3.1.5. During the conduct of paragraph 6.2.3.1.3 through 6.2.3.1.11 monitor the test item as shown in Figure 3 and Figure 4 as applicable. For clarity let Figure 3 serve as an example of measuring techniques to be used to determine the test item's sensitivity parameters using the following assumptions: 36 volts excitation supplied to the potentiometer and a full scale gyro rate range of ±45°/sec. The LVM-5, or equivalent, voltmeter should be read frequently and the impact voltage adjusted to maintain exactly 36 volts. The S.I.E. Model R-1 voltmeter should be allowed 2 minutes warmup, adjusted for zero and then, with the selector on 25 volts the potentiometer driven so that the R-1 reads 18 volts.

a. Mount the test gyro, with its IA vertical and parallel to the rotating axis on the rate table, in the center of a rate of turn table such as a Genisis Mod. C-181.

NOTE: To avoid damaging the friction balls which drive the rate table, be sure the clutch is not engaged when mounting the gyro or its fixture on the table.

b. With the test gyro set up as indicated in Figure 3 perform the following:

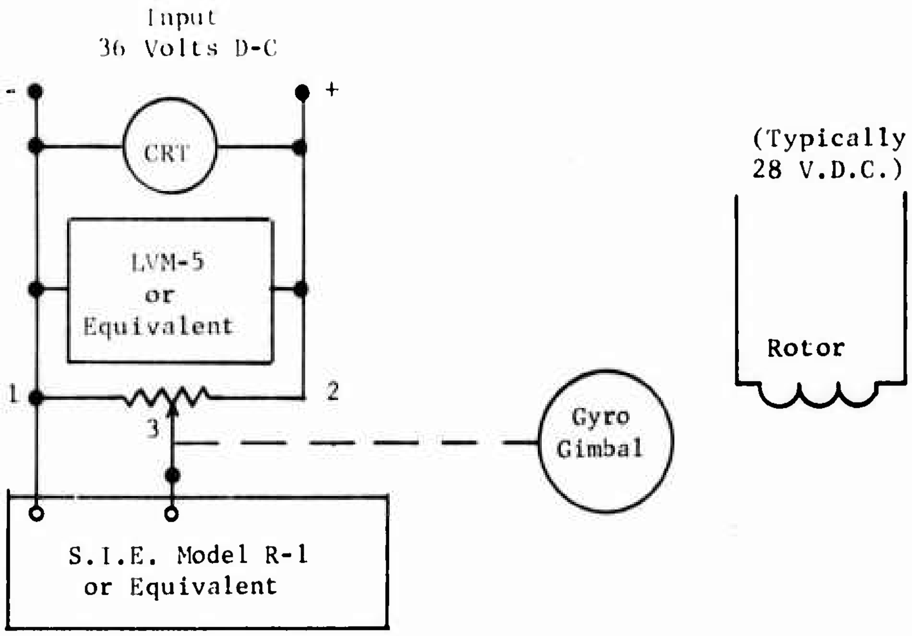


Figure 3. Rate Gyro Measuring Circuit

1) Start the rate table rotating slowly in a clockwise direction.
2) Slowly increase the speed of rotation and monitor the R-1 voltmeter for a minute change in reading. As soon as a voltage change is observed, record the velocity of the rate table as its CW threshold sensitivity.

c. Repeat step b with the rate table rotating in a CCW direction.

6.2.3.1.4 Alternating Component - With the test gyro mounted as described in paragraph 6.2.3.1.3 perform the following:

a. Connect the oscilloscope of Figure 3 across the R-1 voltmeter.
b. Operate the gyro motor with a zero rate input (rate table not spinning) and, using the oscilloscope, determine and record the alternating voltage component peak to peak voltage caused by the gyro motor vibrations.

NOTE: The a-c voltage component shall not exceed the test item's peak to peak specification.

6.2.3.1.5 Range, Hysteresis Error - Perform the following:

a. Determine the zero reference ratio (the static balance point) of the test item as follows:

1) Operate the gyro motor with its rated excitation voltage and a zero rate input.
2) Record the output/input ratio of the gyro potentiometer (pins 1-3/pins 1-2) which is the zero reference ratio.

NOTE: The LVM-5 voltmeter is monitoring the voltage input to the gyro potentiometer across gyro terminals 1(NEG) and 2(POS). The SIE Model R-1 voltmeter is monitoring the output of the gyro potentiometer across gyro terminals 1 and 3. The voltage ratio of terminals 1-3/1-2 (potentiometer output/input) is obtained by dividing the reading of the R-1 voltmeter by the reading of the LVM-5 voltmeter. This method should be used when voltage ratios are required.

b. Start the rate table rotating in a clockwise direction and increase the table's speed until no further voltage change is noted on the R-1 voltmeter. This is an indication that the end point of the gyro potentiometer has been reached. When the end point has been located record the following:

NOTE: 1. When the R-1 voltmeter reads near 35 volts, care must be taken to vary the rate table speed slowly to avoid overshooting the end point. It may be necessary to slightly decrease and increase the speed alternately to pin point the end point exactly. Observing potentiometer wires crossed by means of an oscilloscope in parallel with the R-1 voltmeter may be of help in finding the end point. With the oscilloscope set on a-c and at high gain, a momentary spike will occur when a potentiometer wire is crossed.

2. In searching for the end point, large changes in table speed which cause overshoots and undershoots should be avoided so as not to destroy the gyro hysteresis error.

1) End ratio positive (ER_p) determined from the voltmeter reading/LVM-5 reading.
2) End range positive (E_{r_p}) the rate of the rate table

c. Reduce the rate table rotation to zero as soon as possible within the restrictions of the rate table's manufacturer's instructions.

d. When the rate table zero rate is reached record the hysteresis positive error (H_{pe}) determined by the voltage ratio (R-1 voltmeter/LVM-5 voltmeter).

e. Destroy the hysteresis error by driving the rate table first CCW, then CW, at a low rate until the gyro nulls out at the reference ratio obtained in paragraph 6.2.3.1.1.b.

NOTE: This value should be equal to the zero reference ratio of step a.2.

f. Repeat steps b through e with the rate table rotating in a CCW direction and record the following:

1) End ratio negative (ER_n)
2) End range negative (E_{r_n})

3) Hysteresis negative error (H_{ne})

g. Repeat steps a through f with the following rates of rotation:

1) 25 percent of the normal rotation rate (working range)
2) 50 percent of the normal rotation rate
3) 75 percent of the normal rotation rate

6.2.3.1.6 Resolution, Potentiometer - Determine the number of active wire turns of the potentiometer as follows:

a. Mount the test gyro as indicated in paragraph 6.2.3.1.3.a and instrument the gyro potentiometer and an external potentiometer (number 2) as indicated in Figure 4.

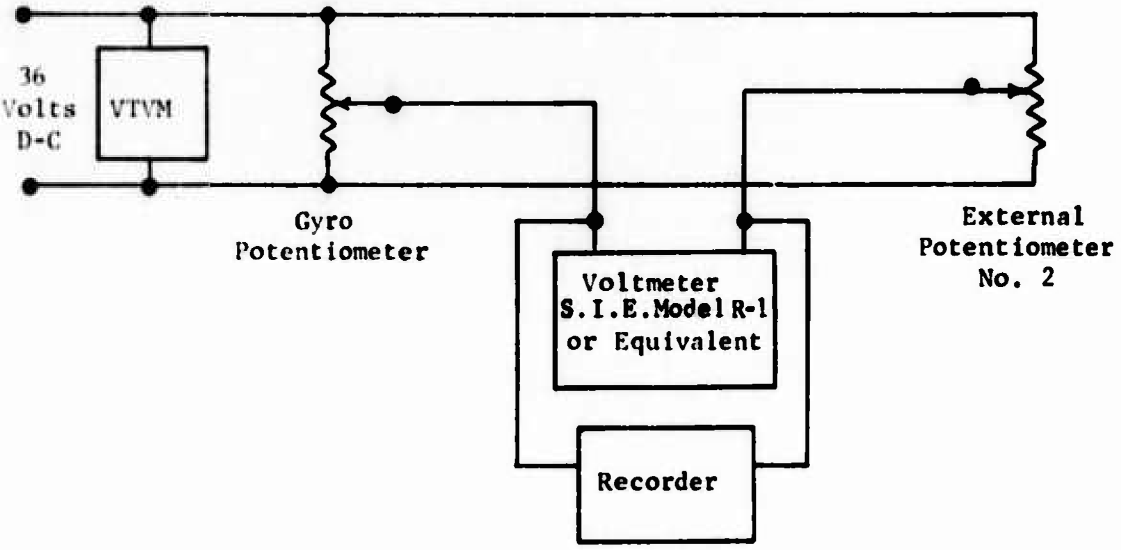


Figure 4. Potentiometer Resolution Measurement

b. Adjust the external potentiometer, with a rate table zero rate, for a zero voltage output as indicated by the R-1 voltmeter and recorder.

c. Determine the proper recorder gain by slowly increasing the input rate to the gyro and adjust the recorder gain until each wire crossed by the potentiometer wiper will show up on the recorder chart as a stair step, with each horizontal step spanning 2 or 3 millimeters. After adjusting the recorder gain reduce the input rate to zero.

d. Adjust the stylus using the centering adjustment to the extreme negative side of the chart paper.

e. Slowly increase the gyro input rate in a CW direction and observe that the recorder is indicating swept wires in the form of steps as indicated in c above. When the recorder reaches the extreme positive edge of the chart, momentarily hold the input constant and return the stylus to the negative edge, then resume the increasing input rate. Continue this procedure until the potentiometer end point is reached.

f. Stop the recorder chart and reduce the input rate to zero.

g. Set the stylus to the extreme positive edge of the chart by means of the centering adjustment and start the chart.

h. Repeat step e with the rate table having a CCW rotation.

NOTE: With the rate table rotation CCW the recorder stylus will move in a negative direction.

i. Remove the chart from the recorder and mark it Chart 2.

6.2.3.1.7 Sensitivity Resolution - Determine the actual minimum change in rate to which the gyro will respond as follows:

a. Prepare the test item for testing by performing the setup of paragraph 6.2.3.1.6 steps a and b and the recorder by adjusting the gain as described in paragraph 6.2.3.1.6.c.

b. Increase the input rate in a CW direction to 25 percent of the normal working range and perform the following:

1) Readjust the external potentiometer (number 2) for zero volts across the R-1.
2) Center the recorder stylus.

c. Carefully and slowly increase the input rate until the recorder steps one step and record the new rate as indicated on the rate table dial.

d. Repeat step c and record the new rate table rate.

e. Repeat step c and record the third rate table rate change.

f. Repeat steps b through e at rates of 50 and 75 percent of the working range.

6.2.3.1.8 Calibration, Repeatability, and Linearity - Return the test setup to the configuration shown in Figure 3.

NOTE: The 36 volts input to the gyro potentiometer (terminals 1 and 2) should be closely monitored by the LVM-5 voltmeter. The R-1 voltmeter used to monitor the gyro output (terminals 1 and 3) should be carefully adjusted and zeroed for d-c voltages.

a. Mount the gyro in the rate of turn table as described in paragraph 6.2.3.1.3.a energize it and ensure that it is running properly.

b. Increase the rate in the CW direction to 10 percent of the gyros working range and record the voltage ratio (terminals 1-3/terminals 1-2).

c. Repeat step b with the rotation rate increased in increments of 10 percent up to 100 percent of the test item's working range.

d. Reduce the rate input to zero and destroy the effects of hysteresis as described in paragraph 6.2.3.1.5.e.

e. Repeat steps b through d with the rate table rotating in the CCW direction.

f. Repeat steps b through e until the steps have been performed for a total of three times.

g. Return the test setup to the configuration of Figure 4 and perform the following with the test gyro operating at its normal excitation voltage.

1) Run the rate table in a CW direction to produce an input rate of approximately 1/3 of the full scale range of the gyro (15 degrees/sec using the example of paragraph 6.2.3.1.3) and note the voltage ratio. Reduce the rate to zero.
2) Repeat step g.1 with the table rotating in a CCW direction.
3) Average the voltage ratios obtained in steps g.1 and g.2 and multiply the result by 36. Record this voltage (the voltage change for plus or minus 15 degrees) as θ_c.

6.2.3.1.9 Friction - Unless the sensitivity resolution determined by conducting the procedures of paragraph 6.2.3.1.7 far exceed the potentiometer resolution determined in paragraph 6.2.3.1.6 the friction test shall not be performed. Should friction tests be required, record the minimum force required to overcome friction.

6.2.3.1.10 Frequency Response - Determine the frequency range within which the gyro will respond to develop an output signal of constant amplitude when a velocity or rate of constant amplitude is applied to the axis.

NOTE:

1. In practice, the useful frequency range of the gyro is not necessarily limited to that narrow band of low frequency at which the response is found to be flat.

2. See Appendix D for a description of the test equipment and the test items characteristics affecting the items frequency response.

3. See paragraph 6.4.3.1.5 for instructions for preparing

response curves and determining percent of critical damping.

a. Mount the gyro in the center of an oscillatory rate simulating table so that the sensitive axis of the gyro is parallel with the axis of rotation of the oscillating table. Take care to avoid damaging the table pivots.

b. Connect the gyro to the test circuitry as described in Figure 4 (paragraph 6.2.3.1.6).

c. Start the rotor by applying 28 volts d-c and turn on the simulator oscillator and amplifier for warmup. Be sure that the oscillator amplitude adjustment is on zero (fully CCW for the Micro-Gee Model 10-C discussed in Appendix D).

d. Adjust the simulator in accordance with the manufacturer's instructions and leave it on standby.

e. Energize the gyro potentiometer with 36 volts. Ensure that the gyro motor is running with the proper voltage.

f. With the gyro level and subject to a zero rate input perform the following:

1) Establish null or R_0 relations between the gyro potentiometer and the external potentiometer No. 2. (see Figure 4) by adjusting the external potentiometer.
2) Adjust the recorder for a deflection, of some convenient value, designated M (i.e. 0.25 volts per millimeter amplitude) and for a chart speed of 25 millimeters per second.
3) Adjust the stylus to the center of the chart.
4) Select the desired input velocity using the criteria given in Appendix D.

g. Set the simulator oscillator on 0.3 cps and turn up the oscillator gain until the peak to peak output, as read on the calibrated recorder, is equal to the voltage value θ_0 obtained in step g of paragraph 6.2.3.1.8.

NOTE: 1. Step g ensures that the peak to peak input and peak to peak output of the gyro are of the correct value for the frequency response and that the gyro is operating within the flat portion of its frequency response curve.

2. Monitor the output velocity signal of the simulator and, for the balance of this procedure, ensure that the velocity signal remains constant. The operating frequency of the simulator will be varied but the velocity must remain the same.

h. Start the recorder and record a minimum of 6 cycles. Stop the recorder.

i. Mark the recorder chart to identify the voltage amplitude and oscillatory frequency in cps.

j. Repeat steps f through i at the following simulator oscillations: 0.5, 0.8, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.0 cps.

k. Repeat steps f through i, in increments of 5 cps, starting at 15 cps and continuing to the maximum allowable as stated in Appendix D (for the hypothetical gyro of paragraph 6.2.3.1.3 25 cps is maximum).

6.2.3.1.11 Natural Frequency - Determine the frequency at which the gyro, in an undamped state, will ring or resonate, as follows:

> NOTE: The method used in this procedure is based on the physical law which states that a 90 degree phase difference exists between the displacement and the velocity of a body in sinusoidal motion, and upon the physical fact that the input-output phase characteristics of a mechanical device, such as a rate gyro, shift by 90 degrees when it is exercised at a frequency to which it is resonant. These two characteristics lend themselves well in determining the resonant or natural frequency of a rate gyro of this type, since the signal from the gyro is a velocity signal and is 90 degrees displaced from an oscillating simulator which has a displacement signal in addition to the velocity signal. It remains only to compare the phase relations between the two signsls, which will be approximately 90 degrees apart at low frequencies.

a. Mount, connect, and energize the test gyro as described in steps a through c of paragraph 6.2.3.1.10.

b. Connect the gyro output (terminals 1 and 2 of Figure 4) in the Y channel of an oscilloscope. Connect the simulator displacement output into the X channel of the oscilloscope to obtain a Lissajous pattern.

c. Start the simulator table operating at 1 or 2 cps and adjust the amplitude of both oscilloscope channels to a convenient trace (2 inches).

d. Gradually increase the frequency of the simulation table while varying the gain of the oscilloscope Y channel to maintain a balanced Lissajous pattern. Record the frequency of the simulating table when the Lissajous pattern collapses to a diagonal straight line. This is the in-phase signal condition which indicates the gyro's natural frequency.

6.2.3.1.12 Case Leak - Determine if a hermetically sealed rate gyro case, filled with about 1/2 atmosphere of inert gas, has any leaks as follows:

a. Place the gyro in a bell jar and, using suitable clamps and blocks, affix a sensitive dial indicator micrometer to the end of the gyro case in such a manner that any expansion of the gyro case will be shown by the dial indicator as displacement.

b. Set the dial indicator to zero.

c. Place a bell jar cover over the gyro/micrometer setup and evaluate the bell jar to 0.5 of mercury (in hg). Record the dial indicator reading.

NOTE: Due to the differential of nearly an atmosphere between the inside and outside of the gyro case, the dial indicator will read a large positive displacement.

d. Maintain the 0.5 in hg in the bell jar for two hours and record the dial indicator reading.

NOTE: A decrease in the reading indicates a case leak.

6.2.3.1.13 Width of the Potentiometer Wiper - Perform the following:

a. Measure the resistance between pins 1 and 2 of Figure 3, paragraph 6.2.3.1.3, using a Shallcross bridge.
b. Move the potentiometer wiper slightly and repeat step a.
c. Repeat step b.
d. Isolate the wiper from the potentiometer by inserting a thin paper between them and repeat step e.

NOTE: If the gyro is hermetically sealed this test cannot be performed unless an identical spare is available.

6.2.3.2 Tests Peculiar to Integrating Rate Gyros of the Floated Gimbal, A-C Pickoff Type

See Appendix E for a discussion of these gyros.

6.2.3.2.1 Flotation Fluid Temperature - Perform the following:

NOTE: The gyro's best performance will be derived when the flotation fluid is at the specific temperature, plus or minus tolerance, called for in the applicable military specifications.

a. Prepare the gyro for testing as follows:

1) Mount the gyro in its fixture, on a suitable test table whose surface is rotatable (a dividing head) so that the gyro output axis (OA) and the table rotating axis (TA) are parallel and horizontal.
2) Connect the gyro output through a demodulation to a recorder.
3) Connect gyro in a closed servo tumbling mode and fully excite it.

NOTE: 1. Best results, for this test, are obtained if the tumbling loop gain is reduced to one-half its normal value.

2. The close servo loop tumbling mode is an operational mode whereby the torque generator control winding can be switched temporarily from a closed servo

loop to another driving current to rotate the gimbal off a desired mount, then switched back again so that a signal generator signal through its amplifier can be made to supply current to the torque generator control dial.

4) Bring the gyro temperature up to the value specified by the manufacturer and allow it to stabilize for 20 minutes.

5) Position the gyro for a minimum or null signal generator (SG) output (E_N) by rotating the gyro in its fixture and record the E_N value.

b. Open the servo loop to the torque generator (TG) and bypass another source of direct current through the control field of the TG to rotate the gyro gimbal in a positive direction until the SG output, as read on the recorder, reaches a predetermined value (i.e. + 15 millivolts).

c. Remove the current from the TG control field and close the gyro's own servo loop. Allow the gyro loop to drive the gimbal back to null E_N.

d. Repeat steps b and c rotating the gimbal in a negative direction.

e. Repeat steps b through d, increasing or decreasing the temperature and allowing time for stabilization, until an operating temperature is found which results in good repeatability of E_N if steps b through d do not give good repeatability (see Figure 5).

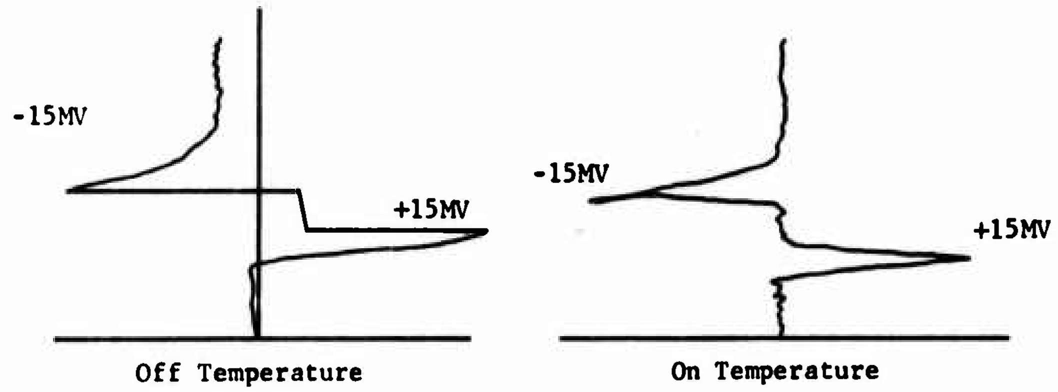


Figure 5. Temperature Test Recording

6.2.3.2.2 Gyro Transfer Function - Perform the following:

a. Prepare the gyro for testing as follows:

1) Mount the gyro in its fixture on a precision right angle bracket, and mount the bracket, in turn, on a dividing head.
2) Orient the gyro so that the IA and dividing head rotating axes are vertical, with the SRA directed north and south. This will orient the OA east and west.
3) Tilt the dividing head 90 degrees toward the west and adjust for gyro level to within allowable limits in two directions, E-W and N-S.
4) Electrically connect the gyro in the open loop mode as shown in Figure 6 and close the DPDT rotation switch (to the TG) to Position 1 and adjust the current in the control field (I_c) to reduce gyro drift near null as indicated by the SG output to less than 0.1 millivolts per second.

NOTE: 1. Analysis of Figure 6 discloses that the current in the TG control and pattern fields is now in series but in phase opposition. The current may be near 2 milliamps.

2. The gyro, as now connected, is in the open loop servo mode allowing the determination of angular displacements of the gyro gimbal and consequently the signal generator.

5) Record the amplitude of the TG current required to maintain the rate or change in SG output to less than 0.1 millivolts.

NOTE: To ensure that the SG output change is less than 0.1 millivolts per second monitor the SG drift for a period of 20 seconds, tabulating the SG output at the beginning and end of the 20 second period.

6) Calculate and record the SG draft rate.

NOTE: The tabulations and calculations of steps 5 and 6 are not directly concerned with the gyro transfer function (GTF) test. They were done merely to set up conditions leading to the GTF test which is described below starting with paragraph 6.2.8.2.2.b.

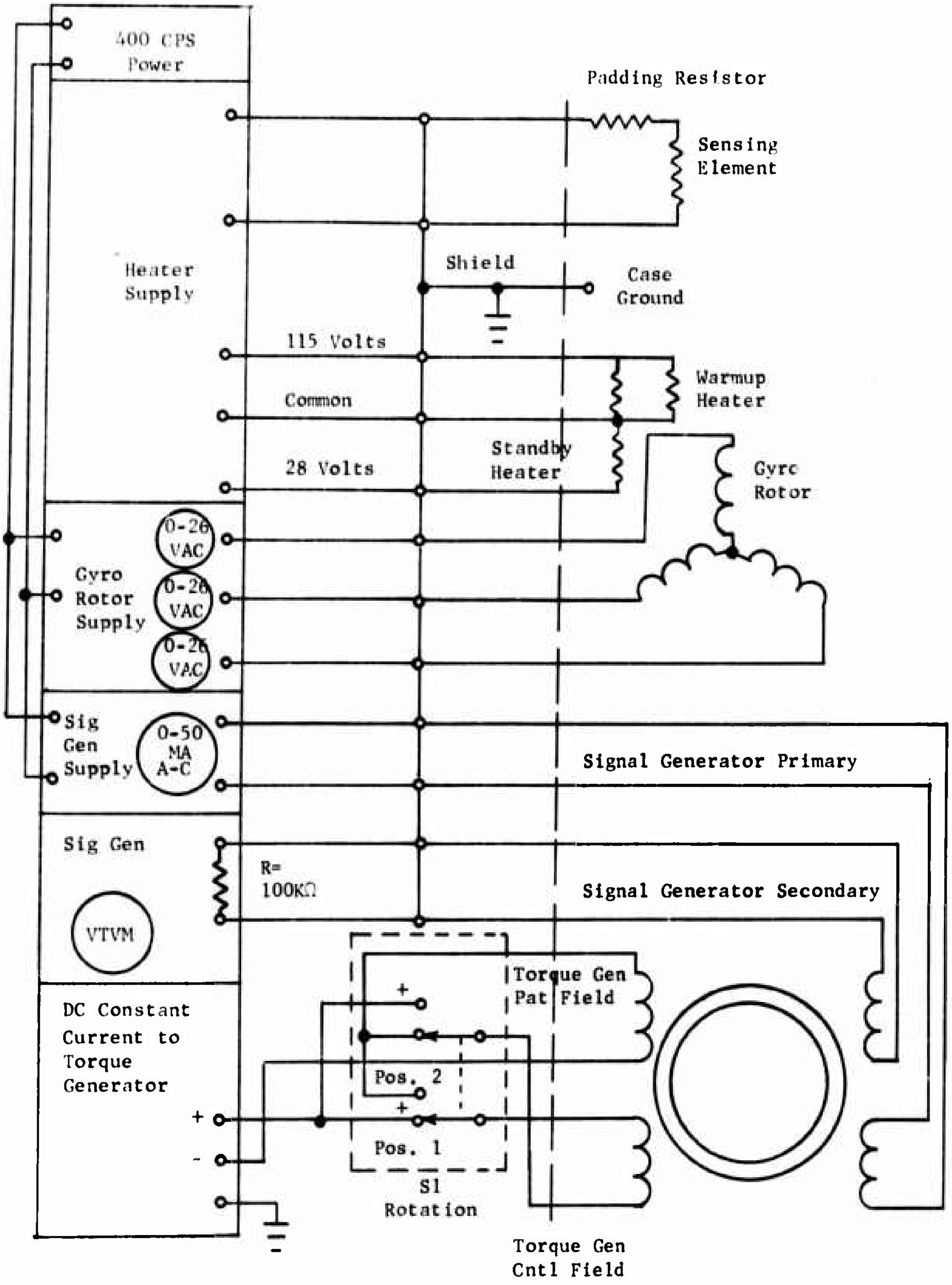


Figure 6. Transfer Function & Gimbal Freedom Tests

b. Rotate the dividing head in a CW direction (looking east into the work) until the SG output is (typically) 175 millivolts. Record the SG output and the dividing head setting to within the specified tolerance (typically 10 arc seconds).

NOTE: Because of elastic restraint forces, gimbal and rotor loads, etc., the gyro gimbal will begin to drift back toward null.

c. Select and record an SG output voltage to be used as a reference point (i.e. 150 millivolts).

d. When the SG output, due to drift, decreases to the reference voltage (150 millivolts) perform the following:

1. Record the dividing head setting.
2. Rotate the dividing head CCW, through null, until the SG output is again 150 millivolts, but in phase opposition, and record the dividing head setting.

e. Repeat steps b through d for a total of four sets of readings.

6.2.3.2.3 Gimbal Freedom Rate - Determine the extent of any restraining forces, including friction, within the gyro which tend to limit the gimbal movement at low input rates, as follows:

NOTE: This test shall be performed under the following restrictions:

1. During testing, do not bump, tap or otherwise distrub the gyro. To do so may have effect of overcoming strictions and invalidating the test data.
2. A gimbal movement through plus and minus two degrees, at a velocity of ten degrees per hour (two-thirds of earth's rate) will be used.
3. From Appendix E, paragraph c, the following assumption is made: The torque in dcm produced in the TG to rotate the gimbal is numerically equal to the product of the currents, in milliamps, in the pattern field (Ip) and the control field (Ic), i.e., = dcm = m^2 (TG torque is always referred to in terms of dcm).
4. For calculations in Appendix F:
    a) SG sensitivity is 5 millivolts/
    b) Angular momentum, H_A, of the gyro wheel = 10^5 gm cm^2/second.

a. Mount the gyro on the surface plate of a dividing head so that when the surface plate is level in both directions, with both dividing head indices on zero, the SRA is normal to the earth's rotational axis (designated position 1 for this test) and the following orientation exists:

1. The OA is horizontal to N and S.
2. The IA is vertical.
3. The SRA is horizontal to E and W.

b. Electrically connect the gyro in the open servo loop mode as indicated in Figure 6.

c. Adjust the current in the TG coils (coils are in series) so that the SG output voltage drift near null will be less than 0.05 millivolts per second.

NOTE: For the example cited in this test, the 0.05 millivolt/second represents a drift rate of about 0.1 m-rad/second and is approximately the SG resolution of an actual gyro.

d. Record the TG current (Ip and Ic) and developed torque (dcm) as determined from dcm = $m^2 (I_p I_c)$. Designate this torque as T_o.

e. Connect a recorder, with its chart set on slow speed, across the SG output.

f. Turn on the recorder and simultaneously impose a gimbal precession rate of 10 degrees per hour in a positive direction by adjusting the current in the coils for a torque equal to $T_o + 4.847$. See Appendix F for the derivation of the 4.847 value.

NOTE: 1. The current passing through the TG coils will be the sum of the current necessary to produce $T_o + \sqrt{4.487}$ and is the required current to obtain the desired rate of gimbal precession of 10 degrees per hour ($\sqrt{4.487} \approx 2.2$ milliamps).

g. Determine and record minimum torque required for the gimbal or OA to be rotated through the selected angle of plus 2 degrees; i.e. $\theta = 2$ degrees (as stipulated in Note 2 of paragraph 6.2.3.2.3) by observing the time required for the SG output, as read on the recorder chart, to reach 175 millivolts. When the SG output reaches 175 mv operate switch S1 of Figure 6 to reverse the TG current and drive the SG back to null, E_N. Should the SG output not reach 175 mv after 5 minutes of operation proceed to step h.

NOTE: The figure 175 mv is used for the following reason: Since 1 m-rad is equal to 0.0573 degrees, the SG output, when θ = 2 degrees, or E_o as a function of two degrees $[f(\theta)]$ may be expressed as : $\frac{2°}{0.0573} = \frac{E_o f(\theta)}{5 \text{ mv}}$

and $E_o f(\theta) = 175$ mv

h. Increase the TG current in 0.5 milliamps until 175 mv is attained and record the required torque. Return the SG output to null as described in step g.

i. Repeat steps b and c so that T_o retains the value it had in step d.

j. Start the recorder and simultaneously impose a gimbal precession of 10 degrees per hour in a negative direction by adjusting the current to produce a torque equal to T_o minus 4.847.

k. Repeat steps g and h.

l. Repeat steps b through k with the gyro oriented in the following positions:

1) Position 2: OA vertical reference end down, IA horizontal to E and W, SRA horizontal to N and S.
2) Position 3: OA horizontal reference end directed toward South, IA horizontal E and W, SRA vertical.
3) Position 4: OA vertical with reference end directed up, IA horizontal E and W, SRA horizontal N and S.

6.2.3.2.4 Null Repeatability - Determine the null repeatability as follows:

NOTE: This test shall be performed under the following conditions:

1. The null position is defined as that IA orientation where all gimbal and all other unbalance forces are equaled and opposed by cancelling internal forces in combination with the earth's rotational effect:

    a) Zero current in the TG control field current
    b) Full rated current in the pattern field as specified by the applicable specification (commonly from 5 to 12 milliamps). Assume 8 milliamps for this test.

2. The gyro circuitry shall be connected in the closed loop servo mode:

    a) SG output leads must be connected through impedance matching circuitry to the input of a servo amplifier and the servo amplifier output connected to the TG control field coil. Figure 6, modified as shown in Figure 7, is recommended as adequate circuitry and consists of the following changes:

        1) The TG control field leads have been removed from switch S1 of Figure 6 and connected to another controllable d-c source in Figure 7.
        2) The two terminals of switch S1 have been shorted together, with hard wire, to provide circuitry to the TG pattern field.
        3) Switch S3 of Figure 7 is set to position 1.

a. Mount the gyro on the leveled surface plate of a precision dividing head oriented as follows:

1) The SRA directed approximately, N and S
2) The IA reference end directed slightly north of east
3) The OA vertical and parallel with the dividing head rotating axis

b. Adjust the current in the TG pattern field to the specified value (8 milliamps has been assumed).

c. Slowly rotate the dividing head in a CW direction as viewed from above (the IA directed eastward) until a position is found where the gyro

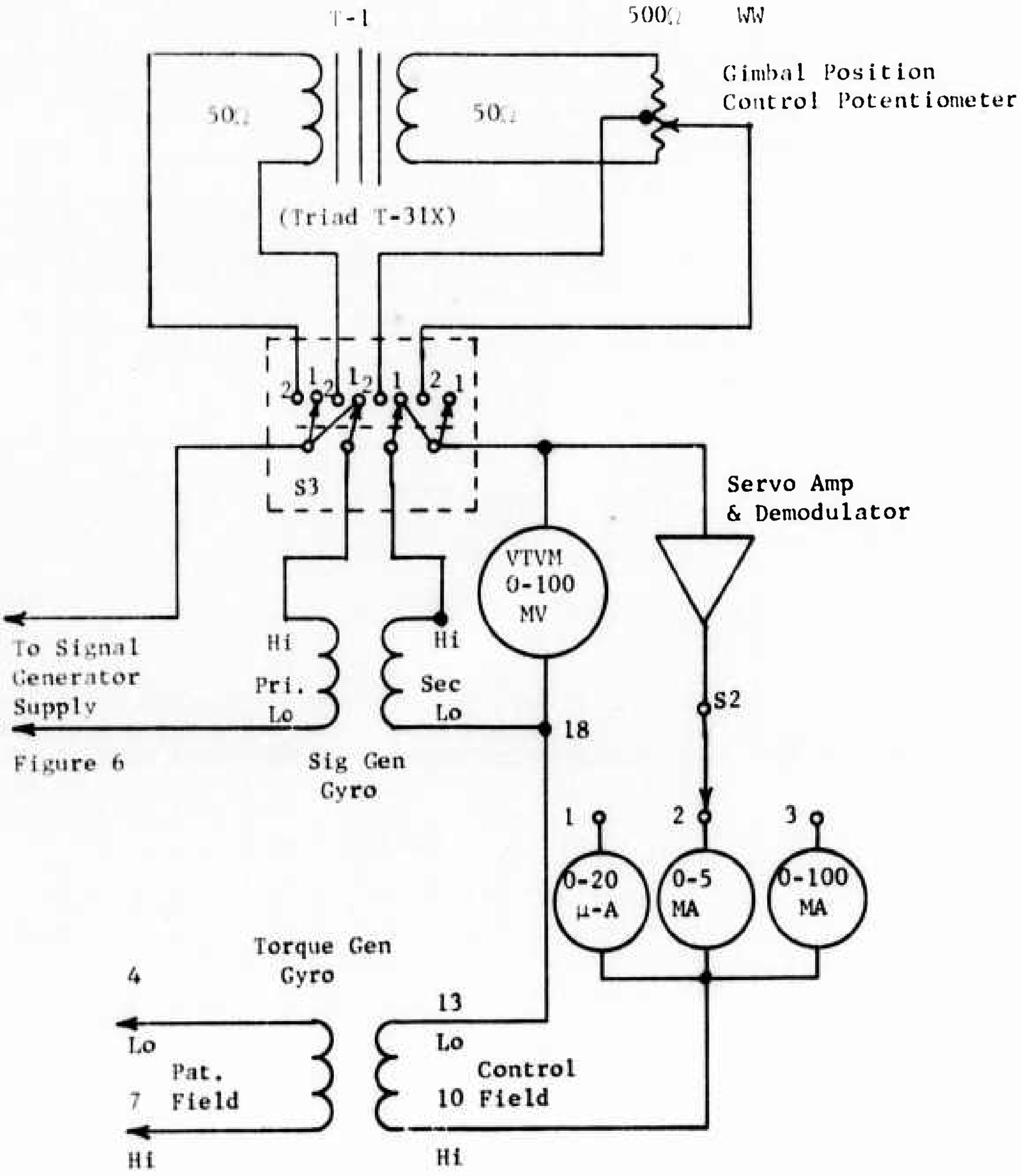


Figure 7. Changes to Figure 6 to Incorporate Closed Loop Servo Operation and Draft Test

drift rate does not exceed 0.02 degrees per hour $[(ma^2)(2.063)]$. Record the dividing head reading to within two arc-seconds, as the CW east null setting.

d. Continue the rotating procedure of step c until a null similar to the one of step c is found with the IA reference directed westward. Record the dividing head setting as the CW west null setting.

e. Place S2 of Figure 7 at position 3, to prevent damage to the microammeter, before continuing to Step f.

f. Rotate the dividing head in a CCW position and locate the east null for a CCW approach. Record the dividing head reading as the CCW east null setting.

g. Continue rotating the dividing head in a CCW direction until the IA gimbal null is determined with the IA reference directed westward. Record the dividing heading setting as the CCW west null setting.

h. From the data of steps c, d, f, and g determine the east null reference and west null reference by averaging the east CW and CCW dividing head settings and the west CW and CCW dividing head settings.

i. Rotate the dividing head in CW to each of the null reference points of step h and record the I_pI_c of the TG for each position.

NOTE: Allow no more than 3 seconds to lapse between positioning the dividing head and heading the I_pI_c values.

j. Rotate the dividing head in a CCW direction to each of the null references point of step h and record the I_pI_c of the TG for each position.

k. Repeat steps i and j until a total of four readings have been taken at each reference null point for both CW and CCW direction dividing head rotation.

l. Determine and record the drift rate for each of the eight readings of steps i through k by multiplying I_pI_c by 2.063.

NOTE: Proceed directly to paragraph 6.2.3.2.5 without disturbing the gyro mounting test set up in any way.

6.2.3.2.5 Fixed Torque - Perform the following:

a. Record the east and west null reference points of paragraph 6.2.3.2.4.h

b. Define and record the true north and south reference positions of the dividing head by bisecting the east and west null reference points of step a.

c. Position switch S3 of Figure 7 to position 1 and switch S2 in the proper position to protect the meters.

NOTE: Current for I_c normally will be 2 microamps or less for east-west reference positions, and much greater (use the milliamp meters) for north-south positions.

d. Rotate the dividing head through two CW and two CCW rotations. Stop at each null reference point during each rotation and record the TG control current I_c, within 3 seconds after bringing the dividing head to the null position and the constant TG pattern current, I_p.

e. Determine and record the drift rate for each of the eight readings of step d by multiplying I_pI_c by 2.063.

NOTE: Proceed directly to paragraph 6.2.3.2.6 without disturbing the gyro mounting test setup in any way.

6.2.3.2.6 Elastic Restraint - Determine the maximum torque exerted on the gimbal by the stiffness of any internal flex conductors, and the TG and SG flux linkage spring equivalent.

NOTE:

1. Elastic restraint is a varying quantity, increasing proportionately with gimbal displacement. Therefore, the test shall be conducted under conditions where the gimbal is actually or simulatedly rotated off from the null position as far or farther than would ever be expected under normal operation.
2. Elastic restraint will herein be expressed as a ratio of torque which causes a gimbal precession rate in degrees per hour per milliradian (mrad) of SG displacement. The SG sensitivity is assumed to be 5 millivolts per milliradian as noted in paragraph 6.2.3.2.3.

a. Position switch S3 to position 2 and switch S2 to the position for the best I_c current reading.

NOTE: I_c may be on the order of 25 microamps.

b. Adjust the SG power supply to 50 milliamps.

c. Adjust the I_p for the required value (8 milliamps for this example).

d. Rotate the dividing head to the east reference null position of principal 6.2.3.2.4.h.

e. Adjust the gimbal control potentiometer (see Figure 7) for (typically) 50 millivolts as read on the VTVM for positive gimbal position. Record the voltage and I_p and I_c.

f. Readjust the gimbal position. Record the voltage and I_c.

6.2.3.2.7 Unbalance, Gimbal and Mass - Determine the rate of drift in degrees per hour contributed by unbalance of the rotor mass (MU_{SRA}) and of the gimbal unbalance (MU_{IA}), and the vector component of unbalance (mass unbalance total) $MU^2_T = MU^2_{SRA} + MU^2_{IA}$, using the closed servo loop mode of paragraph 6.2.3.2.6, as follows:

a. Record the east, west, south and north null reference settings determined in paragraph 6.2.3.2.5 with the north null reference indicated as the up null reference, and the south null reference indicated as the down null reference.

b. Mount the gyro in its fixture directly to a dividing head so that when the dividing head is tilted exactly 90 degrees the OA will be horizontal, directed south, and parallel with the dividing head rotating axis.

c. Rotate the dividing head through two CW and two CCW rotations. Stop at each null reference point during each rotation and record the control coil imbalance current I_c within 3 seconds after bringing the dividing head to the null position, and I_p.

d. Determine and record the drift rate for each of the 4 readings of step c by multiplying $I_p I_c$ by 2.063.

6.2.3.2.8 Axis Alignment - Perform the following:

a. Mount the gyro on an equatorial turntable (sidereal rate table) so that the turntable's rotational axes are parallel to each other and to the earth's rotational axis.

b. Connect the gyro in the open loop servo mode of Figure 6.

c. Rotate the turntable at a low rate (6 revolutions per hour) and record the maximum and minimum (increasing and decreasing) SG output voltage.

NOTE: 1. The misalignment of the gyro axis is determined by converting millivolts per radian into degrees per millivolts, as indicated in Appendix F.

2. If no equatorial table is available, this test, and the test of paragraph 6.2.3.2.9 can be accomplished by mounting the gyro on a rate table and tilting the entire rate table so that the gyro OA, the rate table rotating axis, and the earth's rotational rate are parallel. Then proceed as outlined where the use of the equatorial table is recommended.

6.2.3.2.9 Random Drift (Cogging) - Perform the following:

a. Mount the gyro on an equatorial turntable with the OA, IA, and the earth rotational axis parallel (typically within ten arc minutes).

b. Electrically connect the gyro in a closed loop servo mode as shown in Figure 6 modified to include Figure 7.

c. Connect a tape recorder, having a tape not less than 4 inches wide; to monitor the TG control field current. Reduce the excitation to the TG pattern field to about one-tenth normal, i.e. 1 milliampere.

d. Drive the turntable at a constant rate of one revolution every ninety minutes for two complete CW direction revolutions and two CCW direction revolutions.

e. Ensure that the tape has identifying marks indicating the different gyro positions as it turned through IA east, IA down, IF west, and IA up.

6.3 TEST DATA

6.3.1 Arrival Inspection Tests

Record the following, as applicable:

a. Adequacy of packaging (broken locks, etc.)
b. Container damages (breaks, tears, etc.)
c. Material defects (cracks, bent, etc.)
d. Poor workmanship
e. Compliance with specifications
f. Adequacy of markings

6.3.2 Resistance and Insulation

Record the following:

a. For each resistance value measured:
    1) Test points being measured
    2) Resistance in ohms of:
        a) Calculated value
        b) Measured value

b. For each insulation measurement:
    1) Assemblies/points being measured
    2) Resistance in megohms

c. For dielectric measurements:
    1) Positions being checked
    2) Voltage applied

6.3.3 Procedures Common to All Gyros

6.3.3.1 Phasing

6.3.3.1.1 Rotor Position -

Record the following:

a. Test hemisphere (north, south)
b. Direction of rotation (CW, CCW)
c. Gimbal drive (no motion, driven into stops)

6.3.3.1.2 Pickoff or Signal Generator Phasing -

Record the following:

a. Rate of gimbal precession
b. Direction of gimbal precession

6.3.3.1.3 Signal Generator or Pickoff Characteristics -

Record the following for each half of the secondary winding:

a. Secondary winding under test (3-4, 4-5)
b. E_1 in volts
c. E_2 in volts

6.3.3.2 Rotor Starting Time, Rotor Starting Current and Running Current, and Rotor Friction or Coast Down Time

a. Record the following:

1) For rotor starting time and rotor starting and running currents:

a) Time for the rotor voltage to stabilize
b) Initial voltage in volts (from V_1)
c) Stabilized voltage in volts (from V_1)
d) Initial rotor voltage in volts (from V_2)

2) For rotor friction or count down time:

a) Time required for the rotor to coast down in seconds, as determined from V_2

b. Retain the recorder tape.

6.3.4 <u>Tests Peculiar to Free or Two Degree of Freedom Gyros</u>

6.3.4.1 Tests Peculiar to Free Gyro, A-C Pickoff

6.3.4.1.1 Gimbal Freedom -

Record the following:

a. Starting position of indexing head (original set up, rotated 180°)
b. Pre-tilt output voltage
c. Direction of rotation (CW, CCW)
d. Time required for rotation in seconds
e. Final output voltage

6.3.4.1.2 Gimbal Caging Provisions -

Record the following:

a. Verification of circuit continuity
b. For caging accuracy:

1) Cycle number (1, 2, 3)

2) Gimbal output voltage

c. For backlash:

1) Maximum voltage output:

a) Inner gimbal
b) Outer gimbal

2) Null points passed through:

a) For inner gimbal
b) For outer gimbal

d. For caging and uncaging time:

1) Time required to affect caging in seconds
2) Time required to affect uncaging in seconds
3) Uncaged pickoff null in volts
4) Time required to affect caging, with uncage signal applied in seconds

e. Uncage displacement in degrees
f. Current, in amperes, for:

1) Cage circuit
2) Uncage circuit
3) Each indicating circuit

6.3.4.1.3 Outer Gimbal Sensitivity or Scale Factor (SF) -

Record the following:

a. For open circuit test:

1) Voltage with test item caged
2) For each direction and degree of rotation:

a) Direction of rotation (CW, CCW)
b) Degree of rotation (1°, 3°, etc.)
c) Voltage across load resistor

b. For closed circuit test:

1) Voltage with test item caged
2) For each direction and degree of rotation:

a) Direction of rotation (CW, CCW)
b) Degree of rotation (1°, 3°, etc.)
c) Voltage across load resistor

3) For tracking ability at each degree of table rotation:

   a) Degree of table rotation (5°, 10°, 15° etc.)
   b) Degree of external shift rotation in degrees ±0.05 degrees

6.3.4.1.4 Inner Gimbal Sensitivity or Scale Factor (SF) -

Record the following:

a. Open circuit test:

   1) Voltage with test item caged
   2) For each direction and degree of rotation:

      a) Direction of rotation (CW, CCW)
      b) Degree of rotation (1°, 3°, etc.)
      c) Voltage across load resistor

b. For closed circuit test:

   1) Voltage with test item caged
   2) For each direction and degree of rotation:

      a) Direction of rotation (CW, CCW)
      b) Degree of rotation (1°, 3°, etc.)
      c) Voltage across load resistor

   3) For tracking ability at each degree of table rotation:

      a) Degree of table rotation (5°, 10°, 15°, etc.)
      b) Degree of external shift rotation in degrees ±0.05 degrees

6.3.4.1.5 Slip Ring Test -

Record verification of no intermittent synchro output voltages.

6.3.4.1.6 Alignment of the Axis Gyro -

Record the following:

a. For spin axis alignment:

   1) Peak inner gimbal output, in volts, for:

      a) Clockwise rotation
      b) Counterclockwise rotation

   2) Indication of having passed through null

- b. For outer gimbal perpendicular with inner gimbal:
    - 1) Uncaged, untilted outer gimbal output in volts
    - 2) Tilt angle in degrees
    - 3) Tilted outer gimbal output in volts
- c. For outer gimbal nonorthogonality with the case:
    - 1) For E-1:
        - a) Outer gimbal output, prior to tilt, in volts
        - b) Outer gimbal output, after tilt, in volts
    - 2) For E-2:
        - a) Outer gimbal output, prior to rotation in volts
        - b) Outer gimbal output at 180° rotation, in volts

6.3.4.1.7 Gyro Drift Test -

Record the following:

- a. For static drift:
    - 1) For each position:
        - a) Position number (1, 2, 3, etc.)
        - b) Caged gyro, external synchro null shaft position in degrees
- b. For dynamic drift:
    - 1) For each position:
        - a) Position number
        - b) Caged gyro, external synchro load resistor voltage
        - c) Caged gyro, external synchro null shaft position in degrees

6.3.4.2 Tests Peculiar to Free Gyro, D-C Pickoff, of the Displacement or Amount Type Having a Preset Feature

6.3.4.2.1 Potentiometer Tests -

- a. For resistance values, record the following:
    - 1) Ambient room temperature
    - 2) Resistance, in ohms, across:
        - a) H and J
        - b) G and I

b. For potentiometer resolution retain the recorder graph - Chart I

c. For width of potentiometer contact surface record the following in ohms:

1) JR_1 (resistance between G and H)
2) JR_2 (resistance between G and H after counterclockwise rotation)

6.3.4.2.2 Threshold Sensitivity -

Record the following:

a. Run number (1, 2, or 3)
b. Null reading in volts
c. Indexing head reading at null in degrees
d. Direction of rotation (CW, CCW)
e. Indexing head reading for voltage change in degrees

6.3.4.2.3 Sensitivity Resolution -

Record the following:

a. Setting of the indexing head in degrees (10, 20)
b. VTVM reading in volts
c. Direction of rotation (CW, CCW)
d. Indexing head setting after rotation in degrees

6.3.4.2.4 Null Region -

Record the following for each "tap":

a. Tap being measured (H, G, I, K)
b. For taps G and I:

    1) Indexing head reading, when VTVM reads minimum or null, in degrees
    2) Indexing head reading, when VTVM indicates small output, in degrees

c. For taps H and J:

    1) Indexing head reading, when VTVM stops decreasing in value, in degrees
    2) Indexing head reading, when VTVM indicates decreasing value, in degrees

6.3.4.2.5 Potentiometer Taps, Location -

Record the indexing head reading, in degrees, at the following point:

a. When tap J is reached (maximum positive voltage)
b. When leaving tap J (voltage commences to decrease)
c. When tap I is reached (zero voltage output)
d. When leaving tap I (voltage goes negative)
e. When tap H is reached (maximum negative voltage)
f. When leaving tap H (voltage becomes less negative)
g. When tap G is reached (zero voltage output)
h. When leaving tap G (voltage goes positive)

6.3.5 Tests Peculiar to Rate or Single Degree of Freedom Gyros

6.3.5.1 Tests Peculiar to Common Type Rate Gyros Having a D-C Potentiometer Pickoff

6.3.5.1.1 Static Balance or Null -

a. Input voltage
b. Output voltage (static balance voltage)

6.3.5.1.2 Dynamic Balance -

Record the gyro output in volts at the following positions:

a. Position 1
b. Position 2
c. Position 3

6.3.5.1.3 Threshold Sensitivity -

Record the following:

a. Velocity of the table, causing a voltmeter change, in a CW direction, in degrees per second
b. Velocity of the table, causing a voltmeter change in a CCW direction, in degrees per second

6.3.5.1.4 Alternating Component -

Record the alternating voltage component peak to peak voltage.

6.3.5.1.5 Range, Hysteresis Error -

Record the following for each rotation rate:

a. Rotation rate in degrees per second
b. Output/input ratio (pins 1-3/1 2)
c. End ratio positive (ER_p) (pins 1-3/1-2)
d. End range positive (E_{r_p}) in degrees per second
e. Hysteresis positive error (H_{p_c}) (pins 1-3/1-2)

f. End ratio negative (E_{R_n}) (pin 1-3/1-2)

g. End range negative (E_{r_n}) in degrees per second

h. Hysteresis negative error (H_{nc}) (pins 1-3/1-2)

6.3.5.1.6 Resolution, Potentiometer -

Retain recorder graph Chart 2.

6.3.5.1.7 Sensitivity Resolution -

Record the following for each rotation rate:

a. Rotation rate in degrees per second
b. Rate at which recorder steps one step in degrees per second

6.3.5.1.8 Calibration, Repeatability and Linearity -

a. Record the following for each run:

    1) Run number (1, 2, 3)
    2) Direction of rotation (CW, CCW)
    3) For each rotation rate:

        a) Rotation rate in degrees per second
        b) Voltage ratio (pins 1-3/1-2)

b. Record the following for θ_o:

    1) Direction of rotation (CW, CCW)
    2) Voltage ratio (pins 1-3/1-2)
    3) Value of θ_o

6.3.5.1.9 Friction -

Record the minimum force required to overcome friction, in dcm, when applicable.

6.3.5.1.10 Frequency Response -

a. Record the following:

    1) Recorder deflection, M, in volts per millimeter amplitude
    2) Voltage ratio θ_o (see paragraph 6.3.5.1.8.b.3)

b. Retain the recorder chart.

6.3.5.1.11 Natural Frequency -

Record the frequency of the simulation table, when the Lissajous pattern collapses, in cps.

6.3.5.1.12 Case Leak -

Record the micrometer reading as follows:

a. When the jar was evacuated to 0.5 in hg.
b. After two hours exposure to 0.5 in hg.

6.3.5.1.13 Width of Potentiometer Wiper -

Record the following:

a. Resistance in ohms for each measurement, without inserting paper:

   1) Prior to moving wiper
   2) After moving wiper (Rm)

b. Resistance in ohms with paper inserted (Rp)

6.3.5.2 Tests Peculiar to Integrating Rate Gyros of the Floated Gimbal A-C Pickoff Type

6.3.5.2.1 Flotation Fluid Temperature -

a. Record the temperature resulting in good repeatability.
b. Retain the recorder chart.

6.3.5.2.2 Gyro Transfer Function -

Record the following:

a. For setting up test conditions:

   1) TG current required to maintain the SG output change rate, in amperes
   2) SG drift rate in millivolts per second

b. For gyro transfer function for each set of readings:

   1) Test run number (1, 2, 3, 4)
   2) For typical setup:

      a) SG setting in millivolts
      b) Dividing head setting in degrees-minutes-seconds

   3) Reference voltage in millivolts
   4) Dividing head setting, at CW reference voltage, in degrees-minutes-seconds
   5) Dividing head setting, at CCW reference voltage, in degrees-minutes-seconds

6.3.5.2.3 Gimbal Freedom Rate -

Record the following for each gyro test position:

a. Gyro test position number (1, 2, 3)
b. For initial setting:
    1) TG current in milliamps
    2) Developed torque, T_o, in dcm

c. For driving conditions:
    1) E_o in volts
    2) TG current in milliamps
    3) Required torque in dcm

6.3.5.2.4 Null Repeatability - See Appendix G (page G-1) for a sample data sheet.

Record the following:

a. Dividing head setting in degrees-minutes-seconds ± 2 arc-seconds at:
    1) CW east null setting
    2) CW west null setting
    3) CCW east null setting
    4) CCW west null setting

b. East null reference in degrees-minutes-seconds
c. West null reference in degrees-minutes-seconds
d. For drift rate for each rotation:
    1) Rotation number (1, 2, 3, 4)
    2) Direction of rotation (CW, CCW)
    3) Ip current in milliamps
    4) Ic current for:
        a) East null reference
        b) West null reference

    5) Ip Ic value for:
        a) East null reference
        b) West null reference

    6) Drift rate in degrees per hour for:
        a) East null reference
        b) West null reference

6.3.5.2.5 Fixed Torque - See Appendix G (page G-2) for a sample data sheet.

Record the following:

a. From paragraph 6.3.5.2.4 in degrees-minutes-seconds:

   1) East null reference
   2) West null reference

b. In degrees-minutes-seconds:

   1) North null reference
   2) South null reference

c. Ip current in milliamps
d. For drift rate for each rotation:

   1) Rotation number (1, 2)
   2) Direction of rotation (CW, CCW)
   3) Ic current in milliamps for:

      a) East null reference
      b) South null reference
      c) West null reference
      d) North null reference

   4) Ip Ic value for:

      a) East null reference
      b) South null reference
      c) West null reference
      d) North null reference

   5) Drift rate in degrees per hour for:

      a) East null reference
      b) South null reference
      c) West null reference
      d) North null reference

6.3.5.2.6 Elastic Limit - See Appendix G (page G-3) for sample data sheet.

Record the following:

a. Ip in milliamps
b. For positive SG output:

   1) SG output in millivolts
   2) Ic in milliamps

c. For negative SG output:

    1) SG output in millivolts
    2) Ic in milliamps

6.3.5.2.7 Unbalance, Gimbal and Mass - See Appendix G (page G-4) for sample data sheet.

Record the following:

a. From paragraph 6.3.5.2.5, in degrees-minutes-seconds:

    1) East null reference
    2) South null reference (down null reference)
    3) West null reference
    4) North null reference (up null reference)

b. Ip in milliamps
c. For each mass unbalance measurement:

    1) Rotation number (1, 2)
    2) Direction of rotation
    3) Ic current in milliamps for:

        a) Up null reference
        b) East null reference
        c) Down null reference
        d) West null reference

    4) Ip Ic value for:

        a) Up null reference
        b) East null reference
        c) Down null reference
        d) West null reference

6.3.5.2.8 Axis Alignment - See Appendix G (page G-3) for a sample data sheet.

Record the following:

a. SG excitation in milliamps
b. Turntable rotation rate in revolutions per hour
c. SG output voltage at:

    1) Maximum value
    2) Minimum value

6.3.5.2.9 Random Drift (Cogging) -

Retain the recorder tape.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Procedures Common to All Gyros

6.4.1.1 Rotor Starting and Running Currents

a. Rotor starting currents:

$$I = E/R$$

where: E = Voltage across the load resistor, in volts, measured by V_1
R = Load resistance in ohms

b. Locked rotor voltamperes (VA):

$$VA = IE$$

where: I = rotor starting current derived in step a
E = rotor voltage measured by V_2

c. Rotor running currents:

1) For d-c gyro rotors:

$$I = E/R$$

where: E = Stabilized voltage across a-c load resistor measured by V_1
R = Load resistance in ohms

2) For a-c single phase gyro rotors:

a) For VTVM rms readings same as for d-c gyro rotors
b) For recorder peak-to-peak readings:

$$I_{rms} = \frac{E_{p-p}}{R2\sqrt{2}}$$

$$VA = I^2_{rms} R$$

3) For a-c three phase gyro rotors:

a) For VTVM rms readings:

$$I = \frac{E\sqrt{3}}{R}$$

$$VA = EI\sqrt{3}$$

b) For recorder peak-to-peak readings:

$$I_{rms} = \frac{E_{p-p}\sqrt{3}}{R2\sqrt{2}}$$

$$VA = I^2_{rms}\ 3R$$

6.4.2 Test Peculiar to Free or Two Degree of Freedom Gyros

6.4.2.1 Tests Peculiar to Free Gyro, A-C Pickoff

6.4.2.1.1 Gimbal Freedom -

Gimbal draft in degrees = voltage draft times the scale factor as determined during the conduct of paragraph:

a) 6.2.2.1.3 for the outer gimbal
b) 6.2.2.1.3 for the inner gimbal

6.4.2.1.2 Gimbal Caging Provisions -

a. Caging backlash and backlash:

1) Through gyro operation: record the maximum voltage spread and compare it with specified limits.
2) Through Scorsby table operation (individual backlash):

   a) Compare the maximum voltage output with specifications.

3) Through Scorsby table operation (total backlash - using null):

   a) Null traversed:

      Total caged backlash = two peak voltages - (2 x null voltage)

   b) Null not traversed:

      Total caged backlash = largest peak voltage - smallest peak voltage

6.4.2.1.3 Scale Factors -

Calculate the scale factor (gimbal sensitivity factor) as follows:

a. For open connection sensitivity:

Average the 12 sensitivity readings obtained (millivolts divided by degrees) and compare the resulting sensitivity in millivolts per degree with the test item's specification.

NOTE: This open connection sensitivity shall be used throughout this MTP.

b. For closed connection sensitivity:

Determine the value as described in "a" above.

6.4.2.1.4 Alignment of the Axis of Gyro -

a. Spin axis misalignment with reference to the gyros mounting surface in degrees equals =

1) If null has been passed:

$$\frac{\text{CW peak value + CCW peak value - 2 (null voltage)}}{\text{Scale Factor}}$$

2) If null has not been passed:

$$\frac{\text{CW peak value - CCW peak value}}{\text{Scale Factor}}$$

3) Compare spin axis misalignment with the test item's specifications.

b. Outer gimbal perpendicularity to the inner gimbal:

The outer gimbal synchro voltage difference between the before and aftertilt voltages is an indication of the lack of orthogonality between the inner and outer gimbal axes. This is portrayed in the accompanying sketch:

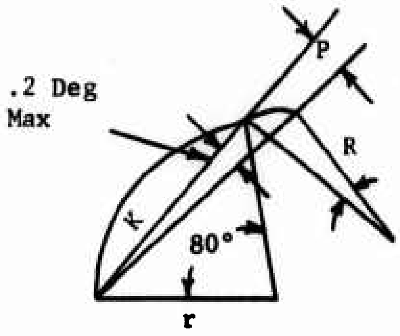
$$K = 2\ r\ \text{Sin}\ \frac{80^\circ}{2}$$

$$P = K\ (0.2^\circ\ \frac{\pi}{180})$$

$$\theta = \frac{P}{R}\ \text{radians}$$

$$\theta = \left[\frac{(2\ r\ \text{Sin}\ \frac{80}{2})(.2\ \frac{\pi}{180})}{R}\right](\frac{180}{\pi})\ \text{deg.}$$

$$\theta = .2568\ \frac{r}{R}\ \text{deg.}$$



where:

r = radius of inner gimbal

R = radius of outer gimbal

θ = rotation of outer gimbal axis due to error in inner gimbal axis

The sensitivity of the gyro outer gimbal was determined in paragraph 6.4.2.1.3. If the difference between the tilted and nontilted voltage is more than the synchro sensitivity multiplied by $0.2568 \frac{r}{R}$ degree, it must be assumed that the inner and outer gimbal axis are out of orthogonality by more than 0.20 degrees. This measurement is only an approximation since factors such as draft and gimbal striction have been neglected.

c. Outer gimbal nonorthogonality with the case:

Nonorthogonality in degrees = $E_1 - E_2$ (outer gimbal scale factor)

where: E_1 = difference between measurements at 0° reference

E_2 = difference between measurements at 180° reference

Outer gimbal scale factor was determined in paragraph 6.4.2.1.3

6.4.2.1.5 Gyro Drift Test -

a. Static drift:

The difference between the external shaft null for each position times the scale factor is static drift of that position. When the earth rate is sensed, the obtained drift shall be corrected for the earth rate. The permissible drift shall not exceed specifications; 0.3 degrees per minute in any of the six standard positions, after being corrected for earth rate, is a common specification.

b. Dynamic drift:

The angular separation between external synchro nulls before and after the test is the dynamic drift. After correcting for earth rate, when applicable, the dynamic drift rate, for any of the six standard positions, should not exceed 0.3 degrees per minute.

6.4.2.2 Tests Peculiar to Free Gyro, D-C Pickoff, of the Displacement or Amount Type Having a Preset Feature

6.4.2.2.1 Potentiometer Tests -

a. Resistance values:

Reduce the average resistance values measured in paragraph 6.2.2.2.1.a to their 68°F equivalent using the following formula:

$$R_x = R_t + R_t a\ (T_1 - T_2)$$

where:

R_x = resistance at T_1 (68°F)

R_t = resistance at ambient temperature T_2

a = temperature coefficient of potentiometer wire 0.004 ohms per degree F is a normal value

Multiply the derived R_x by 4 to determine the total potentiometer resistance.

b. Potentiometer resolution:

1) Percent resolution of the potentiometer = Number of steps in chart 1/100
2) Number of wires in the potentiometer = Number of steps in chart 1
3) Wires per degree (W_{r_d}) = Number of wires/360
4) Resistance per wire (unconnected for temperature) =

$$\frac{(H\text{-}J) + (G\text{-}I)}{2} \times 4/360 \text{ ohms per wire}$$

where: H-J = Resistance across tips H-J measured in paragraph 6.2.2.2.1.a
G-I = Resistance across tips G-I measured in paragraph 6.2.2.2.1.a

c. Width of potentiometer wiper contact surface:

1) $$JR_1 = \frac{(R_1 + R_2 + R_3)(R_{4_1})}{R_1 + R_2 + R_3 + R_{4_1}}$$

where: R_1, R_2 and R_3 are as indicated in Figure 2.

$R_{4_1} = R_4$ of Figure 2.

2) $$JR_2 = \frac{(R_1 + R_2 + R_3)(R_{4_2})}{(R_1 + R_2 + R_3) + R_{4_2}}$$

where: R_{4_2} = R_4 of Figure 2 less 'x' ohms.

$$R_{4_2} = \frac{-JR_2\,(R_1 + R_2 + R_3)}{JR_2 - (R_1 + R_2 + R_3)}$$

3) R_w (shorted resistance of JR_2 'x' ohms) = $R_{4_1} - R_{4_2}$

4) Wiper width (Ww) = $\frac{Rw}{\text{resistance/wire}}$ wires

$= \frac{Ww}{W_{R_d}}$ in degrees

where W_{R_d} was determined in paragraph 6.4.2.2.1.b.3.

6.4.2.2.2 Threshold Sensitivity -

Threshold sensitivity = $\frac{\text{Sum of six indexing head readings}}{6}$ in degrees

(The index head readings were taken in paragraph 6.2.2.2.2 and recorded in paragraph 6.3.4.2.2).

6.4.2.2.3 Sensitivity Resolution -

Sensitivity resolution = $\frac{\text{Sum of Four indexing head readings}}{4}$ in degrees

(The index head readings were taken in paragraph 6.2.2.2.3 and recorded in paragraph 6.3.4.2.3).

6.4.2.2.4 Null Region -

a. Null region (width of tap) in degrees = Indexing head angular difference (at each tap as measured in paragraph 6.2.2.2.4 and recorded in paragraph 6.3.4.2.4) - Sensitivity resolution (determined in paragraph 6.4.2.2.3).

b. Null region (width of tap) in wires = Null region in degrees/wires per degree (W_{R_d})

6.4.3 Tests Peculiar to Rate or Single Degree of Freedom Gyros

6.4.3.1 Tests Peculiar to Common Type Rate Gryros Having a D-C Potentiometer Pickoff

6.4.3.1.1 Dynamic Balance -

a. Calculate the percent of deviation from full scale and record this error on a data sheet. Use the following formula to calculate the percent deviation.

$$\text{Percent deviation} = \frac{E_s \pm E_d \text{ X } 100}{E_p - E_m}$$

where:

E_s = voltage at static balance (recorded in paragraph 6.3.5.1.1)

E_d = voltage under dynamic balance (recorded in paragraph 6.3.5.1.2)

E_p = maximum full range voltage in plus direction

E_m = maximum full range voltage in minus direction

NOTE: E_p and E_m will be obtained later when the calibration and range tests are made (paragraphs 6.2.3.1.5 and 6.2.3.1.8 for maximum value of R-1, voltage output across pins 1-3).

b. If the percent of deviation as derived by use of the formula of step a is almost out of specification tolerance, the gyro should be considered a marginal component and should be subjected to further testing under an acceleration of 15 g's. If, under 15 g's, the deviation is greater than specification allowances, the gyro shall be considered as badly out of balance. However, the test program shall be continued.

6.4.3.1.2 Range, Hysteresis Error - (See paragraph 6.3.5.1.5)

a. Plus minus working range (W_r) = smaller of two values between E_{r_p} and E_{r_p}

where: E_{r_p} = End range positive

E_{r_n} = End range negative

b. Working ratio (WR) = $\dfrac{ER_p - ER_n}{2}$

where: ER_p = End ratio positive

ER_n = End ratio negative

c. Hysteresis error at 100% range (R_o - ratio at zero rate)

$$= \frac{H_{p_e} - H_{n_e}}{WR} \quad \text{(should be 0.500 ± small tolerance)}$$

where: H_{p_e} = Hysteresis positive error

H_{n_e} Hysteresis negative error

6.4.3.1.3 Resolution Potentiometer -

Count the positive and negative steps on Chart 2 and divide into 100 - The result is the potentiometer percent resolution.

6.4.3.1.4 Calibration, Repeatability and Linearity -

a. Average the results of the three sets of voltage ratio recordings of paragraph 6.3.5.1.8.

b. Gyro repeatability and linearity characteristics:

1) Maximum deviation from the average of step a for:

a) CW rotation
b) CCW rotation

c. Plot a graph of output voltage ratios (pins 1-3/1-2) vs. input rates to the gyro and plot the following:

1) Calibration line - The best straight line passing through the average output ratio at zero rate R_o (see paragraph 6.4.3.1.2.c) and through the average plot points of the average output ratios.
2) Tolerance envelope dictated by the applicable military specification.

NOTE: A tolerance envelope usually is specified in the percent of input rate to the full range of the gyro. The tolerance envelope is plotted for quick reference to see if any of the calibration points are out of tolerance. The envelope is derived from the following relation: $\frac{V_{1-3}}{V_{1-2}} = R_o + \frac{I_p}{2\ W_r} \pm \frac{A_e\ I_p}{W_r}$

where:

A_e = allowable error dictated by the specification

R_o = average of two output ratios measured at zero input rate when this rate is approached from clockwise and counter clockwise rates

I_p = input rate in degrees per second (positive for CW rotation and negative for CCW rotation)

W_r = nominal working range as obtained in step 8 of paragraph 3.3.1.5

d. Linearity check: Compute and record the ratio D/O_f for each plot point of the average output voltage ratio versus input rate line where:

D = deviation of any plot point from the calibration line

O_f= full scale output in volts

NOTE: Ratio of D/O_f must not exceed specifications.

6.4.3.1.5 Plotting a Frequency Response Curve and Determining Critical Damping -

a. Plotting a frequency response curve:

1) Refer to paragraph 6.3.5.1.10 for the voltage value θ_o. Note that since θ_o is a d-c value of a plus and minus velocity of 15 degrees per second and the peak-to-peak recorder chart traces obtained in paragraph 6.3.5.1.10 are plus and minus values of an amplitude changing d-c voltage, there is no necessity to reduce these values to rms. Use peak-to-peak chart values (designated now as θ_f) against θ_o at all times. θ_f signifies output voltages at various frequencies of the simulating table and θ_o signifies a voltage output at zero frequency.

2) Refer to paragraph 6.2.3.1.11 (Natural Frequency). Designate the natural frequency as f_n. Also refer to paragraph 6.2.3.1.10 (Frequency Response) and from the identified recorder chart, observe the peak-to-peak voltage amplitude and the corresponding oscillator frequencies at each of the tests conducted in steps g through h. Identify the various voltages as θ_f and the corresponding frequencies as f.

3) On a 3-cycle semi-log graph paper, lay off f/f_n on the abscissa and select the beginning of the third cycle for $f/f_n = 1$. Starting at about half way up on the left ordinate side, select a plot point as unity where $\theta_f/\theta_o = 1$. Now from the identified recorder chart, determine the various voltage amplitudes at the corresponding frequencies. Plot on the graph paper a curve, θ_f/θ_o versus f/f_n. Notice that when the ratio f/f_n is small, θ_f/θ_o will be flat or unity. As f/f_n approaches unity, the ratio θ_f/θ_o will reach a maximum then begin to decrease. The maximum to which the ratio θ_f/θ_o will attain depends upon the percent of critical damping of the gyro. Percent damping will be discussed in the next paragraph.

b. Percent Critical Damping -- Obtain the damping factor λ by comparing the frequency response curve to a family of curves of a simple resonant system.

6.4.3.1.6 Width of the Potentiometer Wiper - See paragraph 6.3.5.1.13

a. Ohms/turn: Resistance prior to moving wiper/number of wires in the potentiometer (see paragraph 6.4.3.1.3 for total number of wires).

b. Width of potentiometer wiper, in turns of wire =

$$\frac{R_p - R_m}{\text{Ohms/turn}}$$

where: R_m = smallest resistance value obtained when moving the potentiometer

R_p = resistance value obtained with paper inserted

6.4.3.2 Tests Peculiar to Integrating Rate Gyros of the Floated Gimbal, A-C Pickoff Type

6.4.3.2.1 Gyro Transfer Function - See paragraph 6.3.5.2.2

a. Record the average SG output voltage (-SG setting to + SG setting) in millivolts.

b. Average the four cw-ccw dividing head angles (arc-minutes).

c. Convert arc-minutes to milliradians by multiplying by 0.291.

d. GTF (gyro transfer function) = SG output change/average input angle

6.4.3.2.2 Null Repeatability - See Appendix G (page G-1) for sample and paragraph 6.3.5.2.4.

a. Summed draft spread = maximum East Null spread + maximum West Null spread

b. Compare the test item's summed draft spread with its specification.

6.4.3.2.3 Fixed Torque - See Appendix G (page G-2) for sample and paragraph 6.3.5.2.5.

a. Average dcm = (torque) for each setting of the input axis (IA) = sum of each cw and ccw dcm value/4

b. Fixed Torque = K = $\frac{\text{IA East + IA West}}{2}$ in degrees/hour

where: K (calibration constant) =

$$\frac{\text{ERU[Cos(local latitude](2.063)}}{\text{IA North - IA South}} \text{ in degrees/hour}$$

ERU = Earth Rate Unit = 15.04 degrees/hour

IA East = Average torque with input axis referenced East

IA South = Average torque with input axis referenced South

IA West = Average torque with input axis referenced West

IA North = Average torque with input axis referenced North

Compare computed draft with specifications.

6.4.3.2.4 Elastic Restraint - See Appendix G (page G-3) for sample and paragraph 6.3.5.2.6.

a. Positive torque in deg/hr = 2.063 I_p (I_c with positive gimbal rotation)

b. Negative torque in deg/hr = 2.063 I_p (I_c with negative gimbal rotation)

c. Turning angle in milliradians =

$$\frac{\text{Positive gimbal rotation voltage - (negative gimbal rotation voltage)}}{\text{SG Sensitivity}}$$

d. Elastic Restraint =

$$\frac{\text{Difference in positive and negative deg/hr}}{\text{Turning angle in Milliradians}} \text{ Deg/hr per milliradian}$$

e. Compare the test item's specification with the calculated result.

6.4.3.2.5 Unbalance, Gimbal and Mass - See Appendix G (page G-4) for sample and paragraph 6.3.5.2.7.

a. Obtain torque (dcm) for each orientation of the input axis (IA) by multiplying the individual $I_p I_c$ values by 2.063.

b. Obtain the average torque for each orientation of the IA axis by dividing the summation of all the individual IA axis values by the number of values. Observe the algebraic sign of the average torque.

c. Obtain the following values:

1) MU_{SRA} = mass unbalance of the spin reference axis

$$= \left[K \frac{\text{IA down} - \text{IA up}}{2}\right] + (E \sin\lambda) \text{ degrees per hour}$$

2) MU_{IA} = mass unbalance of input reference axis

$$= K \left(\frac{\text{IA West} - \text{IA East}}{2}\right) \text{ degrees per hour}$$

3) MU_T = rector sum of the two components of mass unbalance

$$= \sqrt{MU^2_{SRA} + MU^2_{IA}} \text{ deg/hr}$$

where: E = ERU: Earth rate unit at the equation = 15.04 degrees per hour
λ = local latitude
K = Calibration constant: See paragraph 6.4.3.2.3

6.4.3.2.6 Axis Alignment - See Appendix G (page G-3) for sample and paragraph 6.3.5.2.8.

Gyro axis misalignment = maximum output voltage x degrees per millivolt (for the test item) in degrees

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APPENDIX A

INTRODUCTION TO GYROSCOPES

1. GENERAL

A study of missile guidance systems employing gyroscopes has been conducted to determine a sufficiency of test requirements adequate in scope for an engineering evaluation program of guidance system components in the category of both high and low accuracy types.

This pamphlet broadly defines evaluation requirements pertaining to a major inertial component, a gyroscope. The stable platform assembly of a missile system employing purely inertial guidance is considered a high accuracy system and is that assembly which provides a stable reference in flight and can be space stabilized either to space reference or to earth reference. Platform stability is achieved by means of the gyroscope. Generally speaking, a platform consists of three single degree of freedom, integrating type gyroscopes orthogonally mounted to sense movements in the three modes of roll, pitch, and yaw. The sensed signals are routed in the form of error signals through a servo system to reposition the platform to its original position.

2. CHARACTERISTICS

A few major characteristics which are contributing factors to the evaluation of a gyroscope are as follows:

a. Variation in drift rate.

b. Changes of transfer function of the gyro gimbal stabilization loops which could result in gimbal oscillations or in a time lag.

c. Gimbal bearing friction and mass unbalance.

d. Changes in electrical noise, especially the quadrature component.

At this point in the introduction, it is appropriate to discuss a few basic principles related to the various types of gyros now being used in aircraft, missiles, and some types of ground equipment.

The gyroscope basically is a sensor of angular position. Its gyroscopic properties are based on Newton's law of motion and the conservation of momentum. The first law states that a body continues in a state of rest or of uniform motion in a straight line, unless it is compelled by an external force to change that original state. The second law of interest here says that the momentum of a body in motion is the product of the body's mass (m) and its velocity (v). Bear in mind that m is not weight (w), but weight divided by the unit of earth's gravity (g); $m = \frac{w}{g}$. There are two modes of momentum; linear and angular. The mode described by the second law is linear, usually symbolized by the letters H_L. However, since the gyroscope consists basically of a rotating wheel mounted within either two or three frames called gimbals, its usefulness in instrumentation is closely related to the above two basic laws, except that now the interest lies in H_L as a function of the wheel spin radius (r) which is angular momentum (H_A).

A third gyroscopic characteristic closely associated with and derived by reasons of the law of conservation of angular momentum is precession. Precession means that if a force couple is applied to a spinning wheel about an axis perpendicular to the wheel's spin axis (SRA), the resulting rotation will not occur about the axis of the applied force couple; instead, the wheel will process or rotate about a third axis at right angles both to the axis of the applied force couple called the (IA) and to the SRA. This third axis is called the precession or output axis (OA).

3. TESTING METHODS

The following general procedures are recommended to be used throughout the various phases of testing.

Where at all possible, test personnel should adhere to use of specified test facilities, once these have proven effective for specific tests through previous use. The operator of these test instruments should familiarize himself thoroughly with the use of the instruments and adhere to the manufacturer's operating instructions.

Follow instruction manuals closely regarding aspects of operational safety to ensure against high voltages, burns, shock, etc.

When in doubt, test personnel should consult references mentioned in these test procedures or consult supervisor rather than risk ruining test data through misunderstanding or lack of instructions.

Each gyro tested under these test procedures should have a log folder. In this log folder should be entered all the test history of the individual gyro, such as the total number of starts on each test, potentiometer wiper sweeps per test, running time, etc. In addition, the log folder should include permanently entered records, raw data, etc.

4. ROTOR MEASUREMENT TECHNIQUES

Gyro rotors generally fall into three common categories; d-c, a-c single-phase, and a-c three-phase.

For a-c single-phase rotors, the values from the VTVM's may be taken as read because they are rms readings, and $I = \frac{E}{R}$ and $VA = E\,I$ as for d-c. However, if the peak to peak recorder values are used, the equation $I = \frac{E}{R}$ must be modified to $I_{rms} = \frac{E_{P-P}}{R\,2\sqrt{2}}$ and $VA = I^2_{rms}\,R$.

For a-c three-phase rotors, the values from the VTVM's may be taken as read but the equation for I must be changed from $I = \frac{E}{R}$ to $I = \frac{E\sqrt{3}}{R}$, and the equation for volt-amperes will be $VA = E\,I\sqrt{3}$. However, if the peak to peak values of the recorders are used, the equation $I = \frac{E}{R}$ must be modified to $I_{rms} = \frac{E_{P-P}\sqrt{3}}{R\,2\sqrt{2}}$

and the equation for VA becomes VA = I^2_{rms} 3R.

5. DEFINITIONS

A. Radian (rad): The distance from the center of a circle to the periphery of that circle is called the radius (r). A curved length or arc around the circle (not the chord) which is equal in length to the radius is called a radian. This means then that the length of an arc expressed in radians is directly proportionate to the angle scribed by the two radii which contain the arc. Since a full circle contains 360° or 2π radians, the following relationship exists:

$$360° = 2\pi \text{ radians (rad), or}$$

$$1 \text{ rad} = \frac{360}{2\pi} = 57.296 \text{ degrees; conversely}$$

$$1 \text{ deg} = \frac{2\pi}{360} = 0.017453 \text{ radians} = 17.453 \text{ milliradians}$$

B. θ = angular displacement, in rad

C. ω = angular velocity, in rad/sec: The velocity V of a point moving along an arc θ of a circle having a radius (r) is equal to the first derivative $r\frac{d\theta}{dt}$, in other words, the product of the radius (r) and the rate of velocity change $\frac{d\theta}{dt}$ of the angle θ in rad/sec. $\frac{d\theta}{dt}$ is the point's angular velocity about the center of the circle and is designated ω; thus; $\omega = \frac{d\theta}{dt} = v/r$. (1)

D. Angular Momentum (H_A): If a mass (m) is assigned to that point referred to previously and is moving in the circle of radius (r), the instantaneous linear momentum H_L is equal to the product of the radius r and the point's instantaneous velocity (v), thus; $H_L = vm$. From equation (1) $v = \omega r$, substituting (2)
this into equation (2), $H_L = m\omega r$. By definition, angular momentum H_A is the (3)
product of linear momentum H_L and the radius r, it follows that; $H_A = m\omega r^2$. (4)

E. Polar Moment of Inertia (J): Equation (4) contains the term mr^2 which is an expression of inertia J of the mass m revolving about its axis in a circle of radius r. Thus; $J = mr^2$. Equations (4) and (5) lead to a second (5)
expression for angular momentum, thus; $H_A = J\omega$. (6)

F. Torque (K): Newton's second fundamental law states that F (force) equals the product of acceleration (a) and mass (m), F = am. For angular motion, a similar law exists with F replaced by K. K is equal to the product of the moment of the polar inertia J of the mass about the axis of the applied torque, and the angular acceleration a. Thus, K = Ja. Now, since the angular acceleration (8)
(a) is equal to the rate at which the angular velocity ω changes, the following can be related:

$$a = \frac{d\omega}{dt} \qquad (9)$$

If equation (8) is substituted into equation (9), $K = J\frac{d\omega}{dt}$ (10)

Equation (10) often is used for representing basic gyroscopic action.

G. Rate of Precession (ω_o):

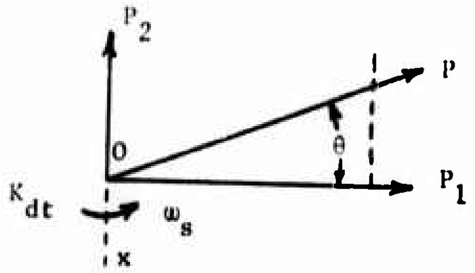


Figure A-1. Angular Momentum

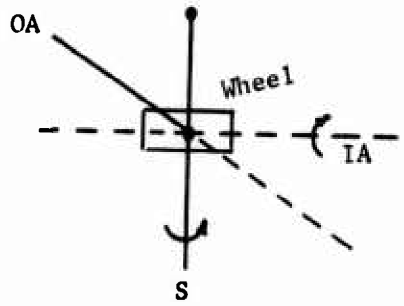


Figure A-2. Precession

To identify the gyro spin wheel properties, let the subscript s be affixed to ω and J. Consider a gyro wheel spinning about its X-axis with an angular velocity ω_s , and having a polar moment of inertia J_s. In accordance with equation (6) an angular momentum will be produced as $H_{A_s} = J_s \omega_s$, represented as O P_1 in Figure A-1. Now consider a torque K being applied about the wheel perpendicular to the spin reference axis X (SRA), that is, about the input axis (IA) (this would be the same as applying a force to push the spot on the SRA in Figure A-2 into the paper). If this torque is maintained for a duration of time dt, an angular acceleration is produced about the wheel which after the time dt will cause the wheel to have a second angular momentum in a direction perpendicular to the original angular momentum. This second angular momentum will have a value equal to Kdt and is represented in Figure 1 as O P_2. The vector magnitude of the two momentums is represented in Figure 1 by O P and the resultant direction is perpendicular both to the direction of the original angular momentum and to the applied torque. It will be about the output axis (OA) as indicated in Figure A-2.

This rotation about the OA is termed precession and it means that the two original forces, H_{A_s} and K, have caused the SRA to take up a new position which is mutually perpendicular to both of the original forces; the angle through which it moved is represented by the angle θ, Figure A-1. The rate at which it turned is designated ω_o (velocity of output).

For infinitely small values of $d\theta$ and dt, as in closed servo loop rate gyros, OP_1 in Figure A-1 may be substituted for OP; then the following derives:

$$d\theta = \frac{Kdt}{J_s \omega_s} \qquad (11) \text{ or}$$

$$K = J_s \omega_s \frac{d\theta}{dt} \qquad (11a)$$

$\frac{d\theta}{dt}$ = is equal to ω_o, the rate of precession or rate of turn of the OA. ω_o can be evaluated from equation (11a) by solving for $\frac{d\theta}{dt}$ which reduces to:

$$\omega_o \text{ or } \frac{d\theta}{dt} = \frac{K}{J_s \omega_s} \qquad (12)$$

From the preceding, it is seen that there are in the study and practice of gyration, three mutually perpendicular axes concerned and three velocities. Number 1 (ω_s) = velocity of spin rotor, Number 2 (Ω) = velocity of input torque about IA, and Number 3 (ω_o) velocity of precession axis or OA.

H. Direction of Precession: A gyro has three axes mutually perpendicular to each other; the spin axis, the output axis, and the sensitive or input axis. By using the right hand rule and pointing the right index finger along the spin axis, the thumb will be parallel to the input axis, and the middle finger will be parallel to the output or precession axis, when the middle finger is bent inward at 90 degrees from the index finger, as shown in Figure A-3.

I. Transfer Function: The definition of transfer function as treated in this pamphlet is intended to embrace aspects of gain, phase shift, lag, and wave form of a gyro's output signal as compared to the amplitude, phase and waveform of the mechanical input. Included in test data analysis and reduction are such gyro characteristics as frequency response, damping, striction, hysteresis, temperature effects and many other contributing factors.

J. Damping: A means of accomplishing damping is built into most gyros to improve stability and to prevent over shooting and hunting. A moving system can be either over-or under-damped. The amount of damping is expressed in terms of percent of critical, which is unity (1). The percent critical usually is referred to as the damping factor or damping coefficient denoted by the symbol "C", or sometimes by the symbol λ (labmda).

K. Gimbal Limit Stops: To prevent gimbal lock, excessive and unnecessary stresses, and possible strains within the gyro mechanisms, mechanical stops generally are provided to limit physically the gyro gimbal rotational capabilities. If the gyro has more than one degree of freedom, one of the gimbals may or may not be limited in its rotational freedom. Detailed methods will be discussed in subsequent paragraphs.

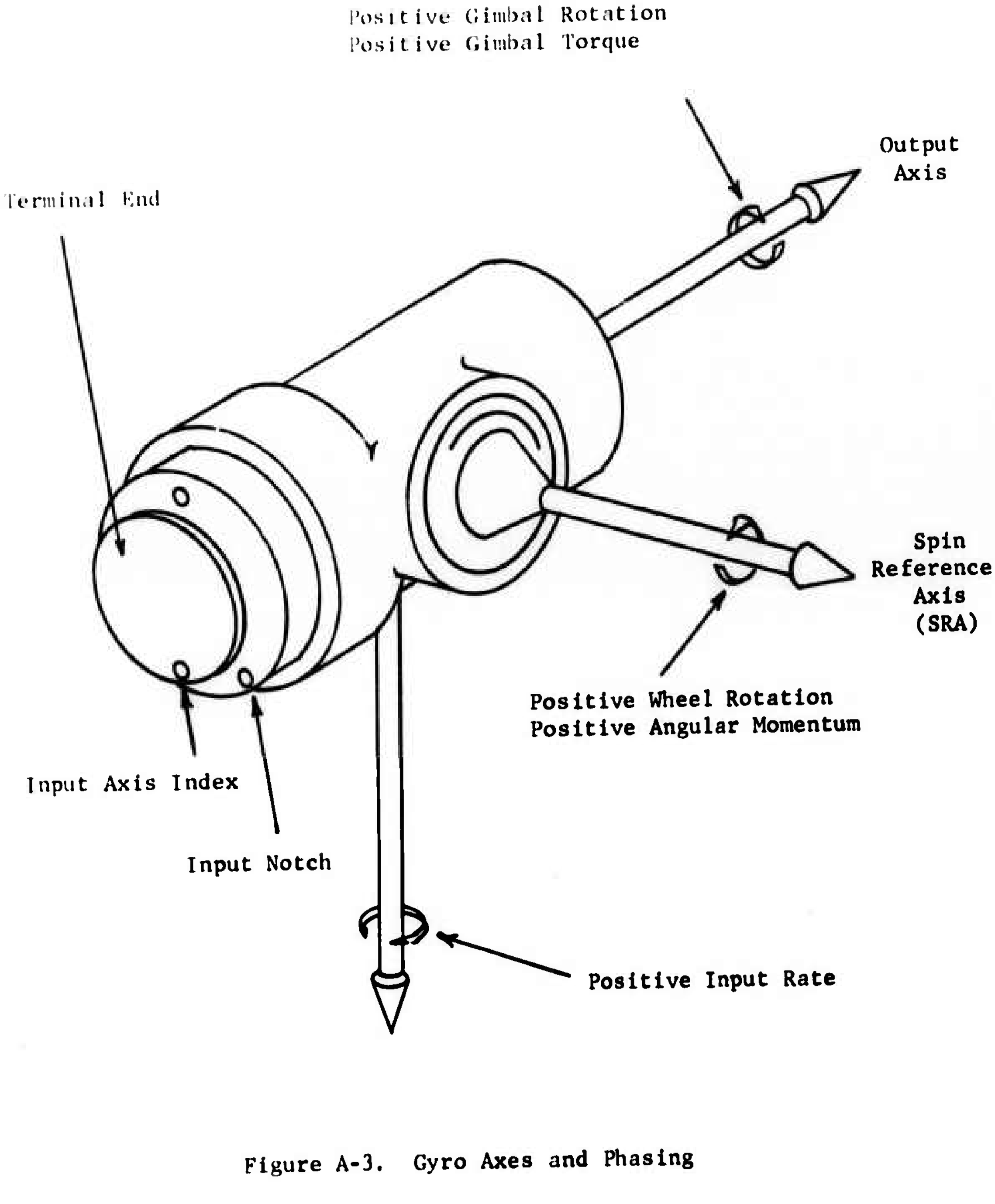


Figure A-3. Gyro Axes and Phasing

L. Torque Generators: Torque generators (sometimes referred to as torque motors) are always used to turn the gyro's gimbals or gimbal, depending upon the degrees of freedom of the specific gyro. The application of torque generators varies widely. In some applications, the torque generator is used to preset the gyro gimbal to a prescribed attitude. In other applications, especially in closed servo-loop rate gyros, it is used to restore the gimbal to a neutral or null position. It is more expedient to treat of torques in subsequent pages in this pamphlet when discussing types of gyros which use them.

M. Caging and Uncaging Time: Caging time requirements usually specify that the cage-uncage mechanism must be capable of uncaging the gyro gimbals within a certain time limit. Another requirement is that the mechanism must be capable of effecting caging within a certain period of time regardless of the position the gimbals may occupy when the caging signal is initiated.

APPENDIX B

TWO DEGREE OF FREEDOM GYROS

Two degrees of freedom means the number of mutually perpendicular planes in which the rotor axis is free to turn with respect to a base, or the number of free gimbals within the gyro case. Three types of gyros considered within this category are (1) the vertical gyro, usually a pitch attitude gyro, which will also sense roll motion, (2) the directional gyro, generally a yaw gyro, which also senses a pitch motion, and (3) the displacement gyro, sometimes called an amount gyro. All of the gyros may have incorporated within their design provisions for presetting or erection to a reference before flight. These gyros generally will be found to have a signal pickoff on each of the two gimbals. These pickoffs may be of the potentiometer type for a-c or d-c, or a synchro a-c pickoff. Test procedures for all two degree of freedom gyros are basically the same. The main difference is in the orientation of the SRA during tests, since the SRA of a vertical gyro is vertical, whereas the SRA of a directional gyro generally is parallel with the longitudinal axis of the aircraft or missile, although it is sometimes athwartship. In this pamphlet, test procedures applicable to two types of free gyros will be discussed. These two detailed procedures will be general enough, yet sufficiently detailed, to serve as guide lines in testing any type of free gyro. The two types discussed will be (1) a directional gyro with the SRA mounted athwartship with an a-c synchro type pickoff, sensitive to roll and yaw motions, and (2) an amount gyro with a d-c potentiometer type pickoff. The SRA of this gyro normally is mounted athwartship to maintain a belly-down-no-roll attitude. The gyro is cageable, and is capable of being preset to desired attitudes. Tests peculiar to the a-c directional gyro will be discussed first.

APPENDIX C

RATE OR SINGLE DEGREE OF FREEDOM GYRO

As in the case of the free gyro, the types of rate gyros are numerous and varied. A detailed discussion of this wide field is beyond the scope of this pamphlet. It is appropriate here to discuss the basic principle of these instruments and their application in the area of aircraft and missile guidance in general, then to discuss detailed test procedures on two of the types in most common use at the present time. These two detailed procedures should be wide enough and sufficiently detailed to serve as guide lines in testing any type of rate gyros.

The two types which this paper discusses are; 1, the common type rate gyro whose output signal is proportional to the rate of turn of a moving craft which in turn would exert a torque about a gyro's input axis if the gyro were properly affixed to that craft. The gyro's output signal would be a rate of turn signal. 2, the integrating rate gyro whose response would be the same as the common rate gyro with the exception of the introduction of a time factor feature. The output signal would then be the integration of rate; hence, angular displacement.

Definition 7 of the Glossary discusses the precessional rate of the gyro at some length. That discussion will now be expanded as it applies to the gyroscopic action of a rate gyro. Consider the drawing in Figure C-1 of a single degree of freedom gyro and observe how it can be developed into a rate of turn measuring device.

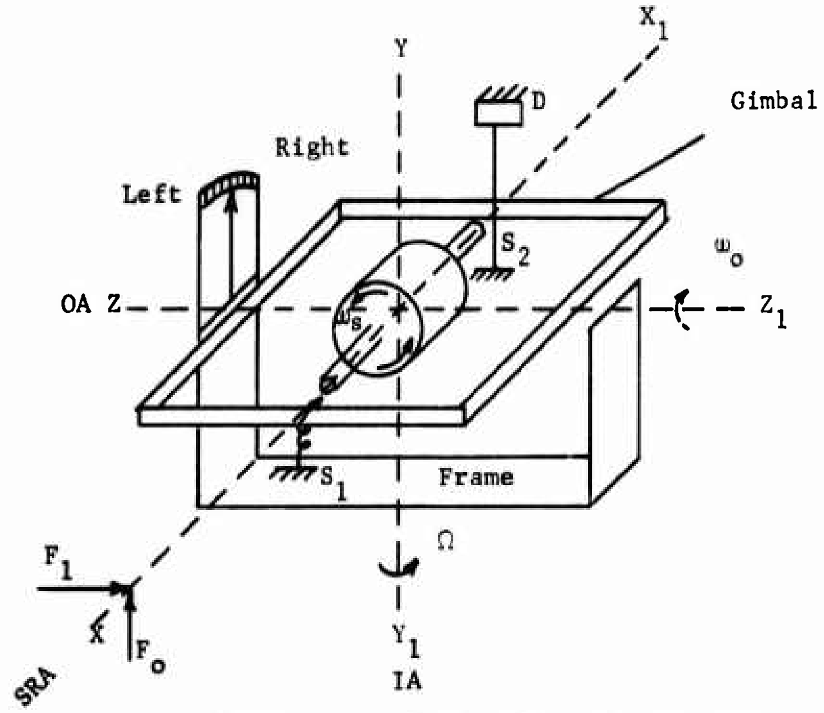


Figure C-1. Development of Rate Gyro

Figure C-1 depicts a typical single degree of freedom gyro. If the frame were rotated Y-Y_1 (input axis IA) in the direction shown, a force F_1 would be caused to act on the spin axis $X - X_1$ in the direction of the arrow F_1. This force F_1 would cause the gyroscopic action of precession to follow. However, in accordance with definition 7 of Appendix A, the precession would be about the axis $Z - Z_1$ (the output axis, OA) in the direction shown by arrow F_o. This means that the spin rotor and the gimbal would move upward from the point X. If the frame rotation about the $Y - Y_1$ (IA) axis were continued and if there were no restraining forces about the $Z - Z_1$ axis, the gimbal would contine to precess or rotate about the $Z - Z_1$ axis until the $X - X_1$ axis and the $Y - Y_1$ axis coincided. At this time, precession would cease because the spin **rotor** axis (SRA) and the input axis (IA) would be parallel and both rotating in the same direction. This is one instance of "gimbal lock". As discussed in the background (see Figure A-1 of Appendix A), the torque K which produced precession about the $Z - Z_1$ axis is directly proportional to the velocity of the spin rotor (ω_s), the moment of inertia of the spin rotor (J_s), and the angular velocity of the input motion of the frame about the $Y - Y_1$ axis. This input angular velocity will be designated Ω. The above statement may be expressed:

$$K = J_s \omega_s \Omega, = H_A \Omega \qquad (1)$$

By the same reasoning if a torque (K) were applied about the $Z - Z_1$ axis in the direction of ω_o of Figure C-1. it would tend to cause the frame to precess about the axis $Y - Y_1$ as the expression:

$$\Omega = \frac{K}{J_s \omega_s} \qquad (2)$$

Equation (1) ($K = J_s \omega_s \Omega$) leads to a widely used application of the single degree of freedom gyroscope, because as has been shown in Definition 6 of Appendix A for a given angular mementum -($J_s \omega_s$), the torque (K) is directly proportioned to an input rate (Ω). Also, from a study of spring characteristics, it is known that they have a spring rate which can be resolved into terms of torque. For the discussion to follow designate this spring rate as (K_s).

Referring to Figure C-1, if two springs such as S_1 and S_2 are attached between the gyro gimbal and the frame, it can be seen that any input angular velocity Ω applied about the IA will develop a precessional torque K about the gimbal OA. It follows that gimbal rotation will cease the instant K becomes balanced by K_s; i.e., $K = K_s$. Then, according to equation (1)

$$K_s = J_s \omega_s \Omega. \qquad (3)$$

As long as the spring is within its stress limits, it is assumed to be linear with respect to the angular deflection of the gimbal. Hence, a calibrated scale attached to the gyro frame and a pointer attached to the gyro gimbal provides a direct means of measuring the input rate Ω. The assembly now becomes a rate gyro. Figure C-1 also shows a dashpot type means of damping (D). The purpose of D is to prevent over shoots and small oscillations and make for stability of the assembly.

The simple scale and pointer shown in Figure C-1 may be replaced by an electrical pickoff such as a potentiometer, synchro, etc. In this manner the rate gyro is readily adaptable in aircraft, missile guidance control, and autopilot systems.

APPENDIX D

FREQUENCY RESPONSE CHARACTERISTICS AND TEST EQUIPMENT

Two mechanical characteristics which largely contribute to defining a frequency response curve are the natural frequency of the gyro and its degree of critical damping.

In all gyros, during the frequency response tests the input rate to the gyro should be maintained in degrees per second at about 1/3 of the gyro's full range.

At the present state-of-the-art oscillatory rate simulators which provide the type of velocity required for conducting a frequency response test and upon which the gyro is to be mounted are limited to about 15 degrees per second when operated at a low frequency of near 0.3 cycle per second (cps). Since the simulator provides a sinusoidal type velocity input to the gyro IA, this input must be ascertained accurately. To obtain a frequency response test of a rate gyro it is necessary that the sinusoidal input rate from the simulator to the gyro be kept at a constant value (1/3 of full range) while the frequency is varied. This means that as the operating frequency of the simulator is increased, the displacement must be decreased correspondingly simultaneously. There are many types of oscillatory rate simulating tables today and most of them are comparable in action. For convenience in discussing this typical procedure, assume that a Micro-Gee Model 10-C Simulator is used.

The peak to peak displacement of this particular simulator in degrees can be monitored by connecting a calibrated recorder or calibrated cathode ray osiclloscope into banana jacks (recorder position and ground negative) on the simulator amplifier. This displacement and voltage can be reduced to RMS velocity if desired, by referring to the voltage versus frequency calibration chart usually supplied with the equipment.

The frequency bands of interest in most present investigations are as follows:

a. 0.3 cps to 25 cps for gyros ± 45 degrees per second range

b. 0.3 cps to 35 cps for gyros ± 100 degrees per second range

c. 0.3 cps to 45 cps for gyros ± 770 degrees per second range

In this hypothetical case the 45 degrees per second gyro is being discussed.

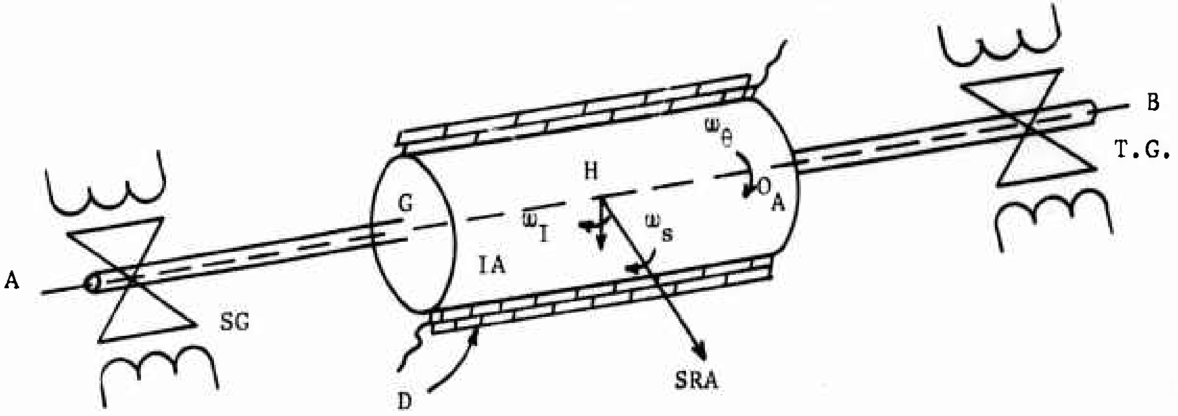
Care must be taken to pass quickly through any resonating frequencies of the simulator table. In the Mod. 10-C simulator, one occurs at about 14.5 cps, and another appears to be around 25 cps.

APPENDIX E

INTEGRATING RATE GYROS OF THE FLOATED GIMBAL, A-C PICKOFF TYPE

A. In contrast to a rate gyro which measures the input rate by comparing the output torque against a calibrated spring, the output torques of an integrating rate gyro are time integrated into gimbal displacements by means of a viscous fluid. The output gimbal of this type of gyro is centered by means of pivots and jeweled bearings positioned between the gimbal and the gyro case. The configuration of the gimbal generally is in the shape of a cylinder, inside of which is placed the gyro wheel. In addition to the aforementioned jewels and pivots, the gimbal cylinder is floated in a viscous fluid sometimes referred to as the damping (D). (D) and the coefficient of damping (C) are two distinct factors. This will be explained later in the discussion. The point to stress at this time is that it is the(C)of the damping fluid which introduces the time element into the intefrating process.

B. Measurement of the gimbal displacement of the gyro under discussion is accomplished by an a-c pickoff or signal generator (microsyn), the rotor and stator of which are affixed to the gimbal and the gyro case, respectively. In addition to the microsyn just memtioned, a second microsyn is mounted similarly to receive electrical command signals to turn the gimbal electrically. This microsyn generally is referred to as the torque generator. When the gyro is operating in a closed servo-loop mode the two generators act to keep the gyro gimbal and rotor wheel constantly positioned to an original reference. Figure E-1 serves to indicate roughly the action-reaction arrangement of an integrating rate gyro.



where:

H = gyroscopic element
TG = torque generator
D = viscous damper
SG = signal generator

Figure E-1. Integrating Rate Gyro

C. Three additional attributes peculiar to this type of gyro justify comment at this time.

Comment No. 1. The flotation fluid used as the damping medium may solidify or become mushy at normal room temperature. Therefore, a pitfall to avoid in handling these instruments is never to subject them to rough handling or sudden, quick movements or vibrations while at this temperature, to do so may shear off the small and delicate internal cabling. There is a danger too, that the pivots and jewel bearings may be cracked, blunted, bent, or otherwise damaged. Because of the fact stated above these gyros are equipped with a means of maintaining a controlled temperature in the region of 190 degrees Fahrenheit when in use.

Comment No. 2. A short discussion on an integrating rate gyro transfer function follows:

Transfer Function (Integrating Rate Gyros). Rate gyro transfer function is defined as the ratio of signal generator output voltage to gyro input angle about the input axis. It is an overall measure of gimbal transfer functions and pickoff sensitivity.

Ideally gimbal motion follows the equation derived from equating precessional torque to the restraining torque:

$$K = H_A \quad \Omega = J_g \frac{d^2\theta_o}{d_t} + C \frac{d\,\theta_o}{dt} + F_g \qquad (1)$$

where:

H_A = angular momentum of the gyro wheel
J_g = polar moment of inertia of the gimbal assembly about the OA
C = damping coefficient of the flotation fluid
θ_o = displacement angle of the gimbal about the output axis OA
F_g = gimbal friction
Ω = input angular velocity about the IA
θ_1 = input angular displacement about the IA

Consider a case (like the gyro under discussion) where the gimbal friction is much less than the precessional torque, and the viscous damping factor is such that any transient term dies out rapidly. Then equation (1) reduces to:

$$H_A \quad \Omega = C \frac{d\theta_o}{dt}$$

If $\Omega = \frac{d0_i}{dt}$, then by substitution it follows:

$$H_A \frac{d\theta_i}{dt} = \frac{C\, d\theta_o}{dt}, \tag{2}$$

$$\frac{\theta_o}{\theta_i} = \frac{H_A}{C}$$

where:

$\frac{\theta_o}{\theta_i}$ is defined as gimbal transfer function

To obtain overall gyro transfer function this last term should be multiplied by the pickoff scale factor (SF) which generally is given as output volts (E_o) per unit of angular displacement of the OA. SF = E_o/θ_o. Thus, for an integrating rate gyro employing viscous transfer and damping means:

$$\frac{\theta_o\ (SF)}{\theta_i} = \frac{H_A\ (SF)}{C},$$

$$\frac{\theta_o}{\theta_i} \times \frac{E_o}{\theta_o} = \frac{H_A\ (SF)}{C} \quad \text{which reduces to}$$

$$\frac{E_o}{\theta_i} = \frac{H_A\ (SF)}{C}, \tag{3}$$

Equation (3) is the transfer function of an integrating rate gyro. If H_A can be held within close tolerances by regulating the speed of the gyro rotor closely, (SF being a constant), the damping coefficient (C) can be varied to obtain the desired transfer function. C, the viscous damping factor, varies inversely with temperature; therefore, adjustment of gyro temperature will produce the desired transfer function. The temperature of the viscous fluid can be controlled as stated in comment No. 1.

Comment No. 3. Gyros of the type under discussion are of high precision and correspondingly high cost, ranging in price from 5000 to 8000 dollars. Thus, it is required that laboratories where these gyros are to be tested are adequately equipped with high accuracy, precision test equipment and that test personnel are of high calibre and well-trained.

Concerning the high precision mentioned, some of the typical required characteristics are as outlined below:

<u>Drift Rates</u>

Fixed or reaction torque	2 deg/hour
Mass unbalance (acceleration sensitive)	2 deg/hour/g
Anisoelastic (acceleration sensitive)	0.02 deg/hour/g^2 rms
Random (repeatability)	0.05 deg/hour

D. Since this type of gyro is of high accuracy and since control of temperature is of utmost importance, it becomes necessary to construct an accurately machined holding fixture including a temperature insulating feature to prevent dissipating heat from the gyro case by conduction. The gyro should be mounted in this fixture for all tests. Refer to Figure E-2 which depicts an internal wiring schematic for a typical integrating rate gyro, as well as typical laboratory electronics required to test a gyro of this type.

In all tests, it is required that the gyro be connected to suitable external electronic control and monitoring circuitry. An attempt to describe the necessary external electronics in this pamphlet is not feasible since the requirements are wide and varied. However, reference to the schematic of Figure E-2 and prior remarks concerning temperature discloses that a means of monitoring and controlling the gyro temperature is required in the external electronics. It is presumed that any laboratory where tests of this type gyro are to be conducted will have the necessary test equipment such as is indicated in Figure E-2. Figure E-2 describes an open servo loop circuitry which is required for some types of tests. Other tests require that the servo loop be closed. This may be accomplished by modifying Figure E-2 to include an amplifier and phase sensitive demodulator connected between the secondary of the gyro SG output and the control field coil of the gyro TG. An adequate modification to the circuitry of Figure E-2 is diagramed in Figure E-3.

E. The useful guidance signals from an integrating rate gyro (IRG) are derived from the SG output voltages and input currents to the TG. There are primary and secondary windings in each of these generators and to obtain any flux linkages that result in calibrated signals (scale factors), the primary windings of each generator must be excited with a nonvariable current. Accordingly, for clarity in citing examples, assume that the primary of the SG will be excited with 50 milliamps alternating current and that the primary coil (pattern field) of the TG will be excited with 10 milliamps of direct current.

Further assume that the milliamp product of the current in the TG pattern field (I_p) and the current in the TG control field (I_c) is directly equal to TG torque expressed in dyne centimeters (dcm). This may be written: dcm = ma^2. Also let the assumed ratio of TG torque to SG voltage output be established as: 5 ma^2 to 1 mv respectively, when the SG sees an impedance of 100 K ohms. In other words, a 5-dcm torque applied to the gyro gimbal produces 1 millivolt of SG output across 100 K ohm resistance. Such a relationship can be arranged by adjusting the servo loop amplifier gain, and is called system calibration.

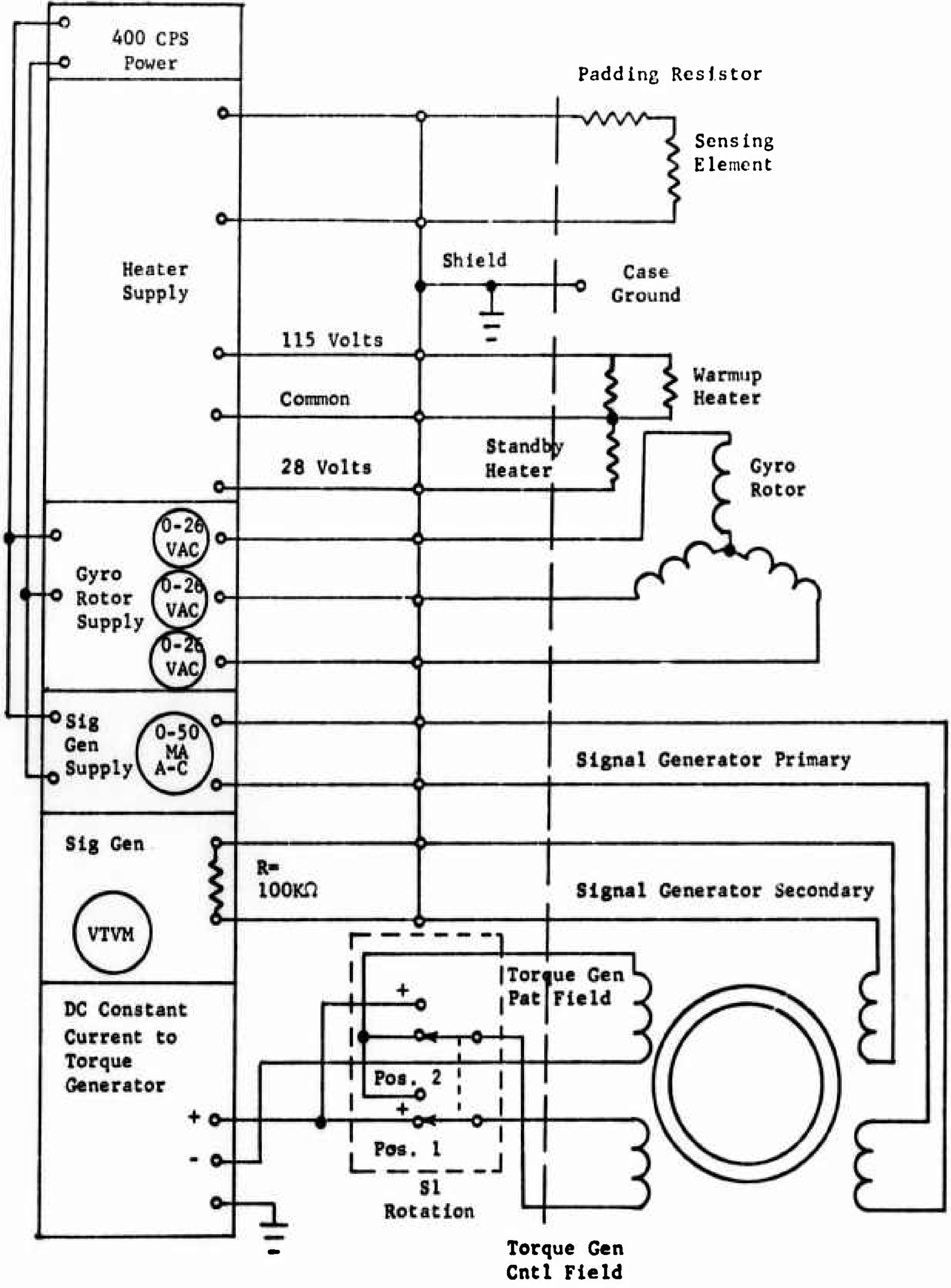


Figure E-2. Transfer Function & Gimbal Freedom Tests

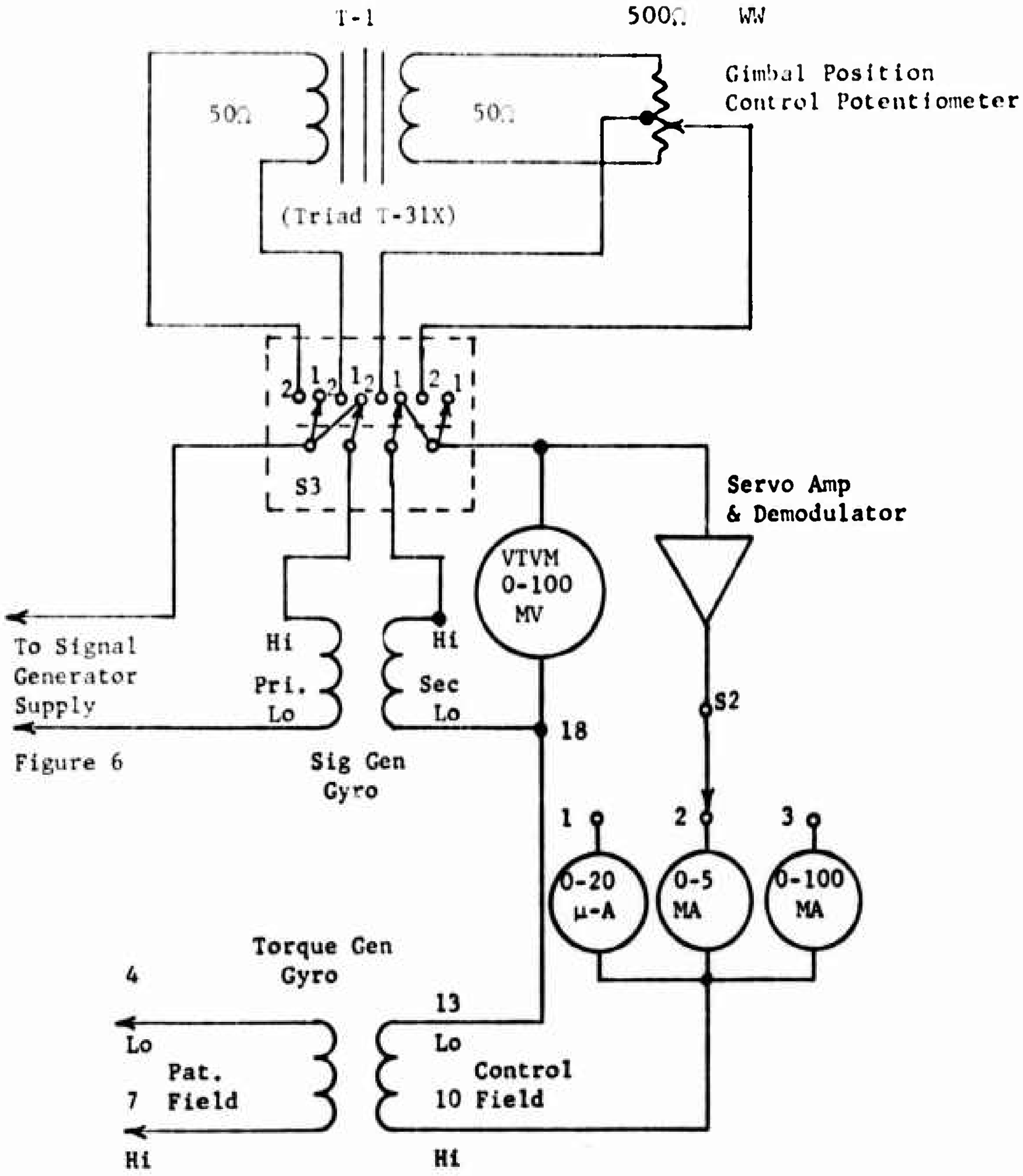


Figure E-3. Changes to Figure E-2 to Incorporate Closed Loop Servo Operation & Drift Test

APPENDIX F

GIMBAL FREEDOM RATE CALCULATIONS

The term 4.847 dcm may generate questions on the part of test personnel. The required input rate of gimbal turn of 10 degrees per hour, can be resolved into a torque of 4.847 dcm and is derived in the following manner, in which it is shown that a torque in dcm can be resolved to a velocity in degrees per hour when multiplied by a conversion factor of 2.063. Remembering the assumption that the gyro wheel angular momentum is 10^5 gm cm^2 per second and referring to the glossary the following can be related:

K = torque in dcm

H_A = angular momentum of wheel = 10^5 gm cm^2 per second (any assumed value of H_A could be taken)

H_A also = $mr^2 \omega_s$, in which

m = mass of gyro wheel

r = radius of gyro wheel

ω_s = velocity of gyro wheel in radians per second

ω_o = rate of gimbal precession in degrees per hour

Now, 1 dyne = 1 gm cm per second^2, therefore, 1 dcm = 1 $\frac{\text{gm cm}^2}{\text{sec}^2}$, and from the law of precession $\omega_o = \frac{K}{H_A}$, therefore,

$$x\omega_o = \frac{\dfrac{1\ \text{gm cm}^2}{\text{sec}^2}}{\dfrac{10^5 \text{gm cm}^2}{\text{sec}^2}} = \frac{10^{-5}\ \text{rad}}{\text{sec}}$$

Note

The numerator 10^{-5} is dimensionless because $H_A = mr^2 \omega_s$, ω_s is dimensionless, being in radians per second. But since ω_s is in radians per second, ω_o is also in radians per second and this must be converted into degrees per hour, thus;

$$x\omega_o = \frac{10^{-5}\ \text{rad}}{\text{sec}} \times \frac{57.3\ \text{deg}}{1\ \text{rad}} \times \frac{3600\ \text{sec}}{1\ \text{hr}},$$

$$x\omega_o = 10^{-5} \times 57.3 \times 3600 = 2.063\ \text{deg/hr}$$

$$x = 2.063/\omega_o \text{ or } 1 = 2.063$$

APPENDIX G

LOCATING EAST & WEST NULL, REFERENCE

LOOKING DOWN ON WORK

DIRECTION	EAST NULL SETTING	WEST NULL SETTING
CW	____ DEG ____ MIN ______ SEC	______ DEG ______ MIN ______ SEC
CCW	____ DEG ____ MIN ______ SEC	______ DEG ______ MIN ______ SEC
$\frac{\text{SUM}}{2}$	____ DEG ____ MIN ______ SEC	______ DEG ______ MIN ______ SEC
	____ DEG ____ MIN ______ SEC	______ DEG ______ MIN ______ SEC

ROTATION TOP VIEW	DRIFT SPREAD REF. TO NULL REFERENCE DRIFT RATE IN DEG/HR = 2.063 I^2 AT EAST NULL	 AT WEST NULL
CW	Deg/Hr	Deg/Hr
CCW	Deg/Hr	Deg/Hr
CW	Deg/Hr	Deg/Hr
CCW	Deg/Hr	Deg/Hr
CW	Deg/Hr	Deg/Hr
CCW	Deg/Hr	Deg/Hr
CW	Deg/Hr	Deg/Hr
CCW	Deg/Hr	Deg/Hr
MAXIMUM SPREAD	Deg/Hr	Deg/Hr

DOES SUMMED DRIFT SPREAD EXCEED SPECIFICATION OF __________ Deg/Hr

GYRO MOD. NO. ____________________ SER No. ____________________

DATE ____________________ ROOM TEMP ____________________ DEG C

OBSERVER ______________________________

Data Sheet 1, Null Repeatability

DIVIDING HEAD REFERENCE POSITIONS

EAST ________ DEG. ______ MIN. ____ SEC.

WEST ________ DEG. ______ MIN. ____ SEC.

SOUTH ________ DEG. ____ MIN. ____ SEC.

NORTH ________ DEG. ____ MIN. ____ SEC.

I_p = ________ MA.

DIR. ROT.	1A EAST		1A SOUTH		1A WEST		1A NORTH	
	Cont.Coil Current	dcm = $I_p I_c$	Cont.Coil Current	dcm = $I_p I_c$	Cont.Coil Current	dcm = $I_p I_c$	Cont. Coil Current	dcm = $I_p I_c$
CW								
CW								
CCW								
CCW								
SUM	╳		╳		╳		╳	
AVE. = $\frac{\text{SUM}}{4}$	╳		╳		╳		╳	

THEN: $\text{FIXED TORQUE} = K = \frac{\text{1A EAST} + \text{1A WEST}}{2} =$ ____________ DEG/HR

WHERE: $K = \frac{\text{ERU [COS(LOCAL LATITUDE)](2.063)}}{\text{1A NORTH} - \text{1A SOUTH}} =$ ______________ DEG/HR

ERU = EARTH RATE UNIT = 15.04 DEG/HOUR

DOES DRIFT EXCEED SPECIFICATIONS? ☐ YES ☐ NO

GYRO MODEL NO. _________ SERIAL NO. _____________

DATE ____________ TEMPERATURE ________ DEG. C

OBSERVER ________________

Data Sheet 2, Fixed Torque

GYRO MOD. ______________ SER. NO. ________________ DATE ____________

ROOM TEMP. ______________ DEG. C. OBSERVER ________________

ELASTIC RESTRAINT Data Sheet 3A

PATTERN FIELD CUR = ________________________ MA(8)

	GIMBAL ROTATION	CONT. FLD I	DEG/HR = 2.063 I^2
(a)	STEP 1 POSITIVE = + _____MV.	_________ MA	- __________DEG/HR
(b)	STEP 2 NEGATIVE = - _____MV.	_________ MA	+ __________DEG/HR
(c)	STEP 1 & 2 a-b 100 MV.		__________DEG/HR

ELASTIC RESTRAINT = $\frac{(c)\ \text{DEG/HRx5}}{(c)\ \text{MV.}} = \frac{\_\_\_\_\_\_\text{x5}}{100}$ DEG/HR PER RAD

DOES DRIFT EXCEED SPECIFIED Deg/hr? PER MR? ☐ YES ☐ NO
/Per MR

AXIS ALIGNMENT DATA SHEET 3B

SIGNAL GEN. EXCITATION __________ MA (50)

TURNTABLE VELOCITY __________ RPM

MAX. SIGNAL GEN. OUTPUT

VOLTAGE __________ MV.

OP VOLTAGE EXPRESSED

IN DEGREES (OPX) (0.01146) = __________ DEG

IS SPECIFICATION EXCEEDED? ☐ YES ☐ NO

Data Sheet 3, Elastic Restraint
and Axis Alignment

GYRO MOD. NO. ________ SERIAL NO. ____________ DATE ____________

ROOM TEMP. ____________ DEG. C. OBSERVER ________________

DIV. HEAD NULL REF. From Fig. 8 UP-NORTH __ DEG___'___" EAST __ DEG___'___" DOWN-SOUTH __ DEG___'___" WEST __DEG ___'___"

LOCAL LATITUDE ANGLE (λ) ___'___", SIN LAT = 0.______ = SIN λ

ERU = 15.04 $^{\text{DEG}}/\text{HOUR}$; K = ____________

TORQUE GENERATOR PATTERN FLD CURRENT = MA(8)

Rotation Looking Do	ORIENTATION OF INPUT AXIS (IA)							
	UP		EAST		DOWN		WEST	
	Cont.Coil Cur. (MA)	Torque (DCM)	Cont. Coil Cur.(MA)	Torque (DCM)	Cont. Coil Cur.(MA)	Torque (DCM)	Cont. Coil Cur.(MA)	Torque (DCM)
CW								
CW								
CCW								
CCW								
TOTALS								
AVE = $\frac{\text{TOTALS}}{4}$		a		b		c		d
TORQUE SPREAD								

MAX. TORQUE SPREAD = ____________ x 2.063 = ____________ DEG/HR

$MU_{SRA} = [K(\frac{c-a}{2})] + (E \sin \lambda)$ = ________________ DEG/HR

$MU_{IA} = K(\frac{d-b}{2})$ = ________________ DEG/HR

$MU_T = \sqrt{\overline{MU}^2_{SRA} + \overline{MU}^2_A}$ = ________________ DEG/HR

DOES MU EXCEED SPECIFICATION?

☐ YES
☐ NO

E = ERU AT EQUATOR

λ = LOCAL LATITUDE

Data Sheet 4, Mass Unbalance