GRAVITY PROBE B
PROCEDURE FOR
PAYLOAD VERIFICATION
P0516 Rev A
GYRO SLOW SPIN TEST

10/23/2000

Prepared by: C. Gray

Approvals:

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<tr>
<th>Program Responsibility</th>
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<td>C. Gray</td>
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<td>R. Brumley</td>
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<td>M. Taber</td>
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<td>Payload Test Director</td>
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<td>D. Ross</td>
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<td>GP-B Quality Assurance</td>
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<td>B. Muhlfelder</td>
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<tr>
<td>Hardware Test Leader</td>
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NOTES:
Level of QA required during performance of this procedure:
Stanford QA Representative
Government QA Representative

All redlines must be approved by QA
Gravity Probe B

10/23/00

Gyro Slow Spin Test

Procedure No. P0516 Rev A

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Revision Record:

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<td>Redline changes from the last payload test have been incorporated. A contingency for unexpected rotor delevitation has been explicitly called out.</td>
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A **Scope**

This procedure covers the spin-up of gyroscopes at room temperature in Probe C. It is only intended for very low-frequency spins.

B **Requirements Verification**

B.1 Requirements Cross Reference: none

B.2 Expected Data for verification per requirement: none

C **Configuration Requirements**

Probe C is installed into the dewar and being pumped out by the Leakage Gas Management pumping system. The gyroscope is levitated.

D **Hardware Required**

D.1 Flight hardware required

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D.2 Commercial test equipment

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D.3 Mechanical/Electrical Special test equipment

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<td>Gyro spinup gas management system</td>
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D.4 Tools

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D.5 Expendables

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E  Software Required
N/A

F  Procedures Required
N/A

G  Equipment Pretest Requirements
N/A

H  Personnel Requirements
The following personnel have received extensive training in the testing of GP-B gyroscopes and are qualified to perform this procedure.

- David Hipkins
- Bruce Clarke
- Chris Gray
- Robert Brumley
- Dr. Sasha Buchman
- Dr. William Bencze

I  Safety Requirements

I.1  General
It is important to be cognizant at all times of the position of the probe. Be extremely careful not to accidentally bump into the probe. If any connector does not connect smoothly and securely, do not try to force it. Instead, remove the connector and inspect it to find the reason for the difficulty. Great care must be taken at all times during the performance of this procedure.

I.2  Electrostatic Discharge
Grounded wrist straps are to be worn at all times when mating or demating to an electrical connector on Probe C.

I.3  Personnel Safety
All operations shall take place according to Stanford University safety guidelines. Any person observing a situation that they deem unsafe shall report the fact immediately to the test director. The Quality Assurance representative shall be responsible for monitoring that all activities are performed in a safe manner.

I.4  Electrical mating and demating of flight hardware connectors
I.4.1 Connection and disconnection shall be performed only when the equipment involved is in a powered-down state unless the procedure specifically states otherwise.
I.4.2 Connector savers are to be used unless otherwise specified.
I.4.3 Connectors shall be inspected for contamination and for bent, damaged, or
J.4.4 Grounded wrist straps are to be worn prior to removal of connector caps or covers and during mating/demating operations.

J.4.5 ESD-protective caps or covers are to be immediately installed after demating of connectors.

J. General Instructions

J.1 Redline Authority

Redlines can be initiated by any of the qualified operators listed in section H and must be approved by QA.

J.2 Discrepancies

Any nonconformance or test anomaly should be reported by a Discrepancy Report. Refer to the Quality Plan, P0108, for guidance. Do not alter or break test configuration if a test failure occurs; notify quality assurance.

J.3 Test Exit Authority

Only the following persons have the authority to exit/terminate this test or perform a retest:

Rob Brumley, Chris Gray, David Hipkins, Bruce Clarke, Sasha Buchman, William Bencze, and QA personnel.

J.4 Gyroscope Delevitation

If a gyroscope delevitates during the completion of this procedure, all work shall cease and the test configuration shall not be broken. Work may only continue under the guidance of the MRB. A Discrepancy Report shall be immediately opened recording the details of what happened. The immediate concern of the investigation should be to determine whether the GSE was at fault in the delevitation and how this GSE should be re-tested on non-flight gyroscopes prior to attempting levitation on a flight gyroscope.

The delevitation of a gyroscope does not necessarily mean that the gyroscope fails the test altogether. The voltages necessary for ground levitation cause an extreme over-test, and it is expected that arcs due to field emission may occur from time to time. However, if a gyroscope does delevitate it will be necessary to conduct a certain amount of penalty testing. The exact nature of this penalty testing will depend on the details of the gyroscope delevitation, and therefore can not be indicated here (it will be under the control of the MRB). However, the following shall be used as a guideline for a standard set of penalty testing:

- Relevitation according to P0481
- Exploration of the housing (exact ranges may vary according the judgement of the MRB).
- New spindown test of the gyroscope (exact positions used and time spans used are at the discretion of the MRB).
K References and Applicable Documents
L. OPERATIONS

The following sections detail how to spin the different gyroscopes. Complete only the sections indicated as relevant to the gyro being spun. Mark which sections are to be completed as part of this procedure.

☐ Section L1-L5 for Gyro #1
☐ Section L6-L10 for Gyro #2
☐ Section L11-L15 for Gyro #3
☐ Section L16-L20 for Gyro #4

L.1 Pre Spin-Up Checklist Gyro 1

Start Date: ______________________
Start Time: ______________________
Gyroscope #: ____________________

L.1.1 Verify the gyroscope is levitated and in the desired position

Record Position [X Y Z]: ______________________________

L.1.2 Verify that the gyroscope is not charged >70 volts

L.1.3 Verify that there is no oscillation in the position greater than 40 micro-inches.

L.1.4 Verify that the gyroscope has been levitated for at least one hour

L.1.5 Leakage Gas Pumping System is operating and the system Pressure < 5 x 10^{-5} torr

L.1.6 Spinup Exhaust Pumping System is operating and pressure is <5 x 10^{-3} torr (this is used to evacuate the spinup manifold)

L.1.7 Confirm manifold between the Probe C Gyro inlets (S1, S2, S3, or S4) and the Gyro Spinup management manifold (GSV-7) is connected, under vacuum, and has been certified according to P0567. Record Op. Log number:

L.1.8 Confirm the helium spinup gas supply is Grade 6 He and has Conformance Certification available.
L.2 Spinup Manifold Evacuation for Gyro 1

**Note:** Refer to figure 1 for pumping system schematic.

L.2.1 Check that SEP-1/SEP-2 pumps are operating and the pressure is < 5 x 10^{-3} torr. If the pumps are not running pressing the momentary switches on the right side of the schematic can start them. Place the system in Interlock Defeat mode and verify yellow LED is blinking.

L.2.2 Open auxiliary valves AXV-8, AXV-5, and the gas supply valve GSV-7. This will evacuate the spinup manifold up to the flow controller GSV-4. Confirm the Probe spinup valve is open. If it is not, gently open the Probe spinup inlet valve, S1. Close valves AXV-8, AXV-5, and GSV-7.

L.2.3 Turn off interlock defeat. The system is now ready to initiate Bypass flow.

L.3 Initiate Bypass flow for Gyro 1

L.3.1 Check to ensure the Spinup gas supply bottle has > 250psi. Open V5 and V6 at the helium supply bottle.

L.3.2 Open GSV-1 and GSV-2 (100 sccm flow controller).

L.3.3 Open GSV-6

L.3.4 Set GSV-4 mode switch to “auto” and rotate the 10-turn pot clockwise on GSV-2 until the desired flow is displayed on GSG-4. **Note:** The numbers on the 10-turn pot dial will correspond with the output of the flow controller. Start recording spin information in Table 1.

L.4 Gyroscope Spinup for Gyro 1

L.4.1 Start a FFT file on the Sun 386i. Record File name: ____________________

Record any additional useful information concerning the spin speed readout in the lines below (e.g. type of readout used, if the SQUIDs are being used, what range and gain are they on, etc.).

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L.4.2 When you are ready to start spinning the Gyroscope, open GSV-7.

L.4.3 Confirm GSV-6 closed while GSV-7 was opened.

L.4.4 Flow gas into the Spinup manifold. Monitor spin speed on the Sun 386i. Continue to record spin information in Table 1.

L.4.5 To stop spinup (either because the target spin speed has been reached, or to assess how the spinup is proceeding) open GSV-6 to reinitiate a bypass flow.

L.4.6 Steps L.4.1 – L.4.4 should be repeated as necessary to spin the gyroscope. Initially, use only a few sccm for a few seconds to get a feel for the spinup. This may be gradually increased as necessary. If it is uncertain whether or not the gyroscope is spinning after several attempts, stop the process and assess the situation.
## Table 1-Gyro 1 Spinup

<table>
<thead>
<tr>
<th>Time</th>
<th>Flow Rate (sccm)</th>
<th>Length of Flow</th>
<th>Gyro Spin Speed</th>
<th>Comments</th>
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</table>
L.5 Post–Spinup Procedure for Gyro 1

L.5.1 Turn the 10-turn pot counter clockwise until gas is no longer flowing. Display reads 000. Set the GSV-4 switch to “off”.

L.5.2 Close GSV-1 and GSV-2 to stop the flow of gas.
   Close GSV-6
   Open AXV-8 and AXV-5
   Turn on Interlock Defeat and Open GSV-7

L.5.3 Let the SEP pumps evacuate the manifold from the flow controller to the Gyroscope. This will evacuate some of the remaining He left in the spinup manifold.

L.5.4 (Optional) Gently close S1 on the Probe spinup inlet. Check if done: _______

L.5.5 Close GSV-7, AXV-5 and AXV-8

L.5.6 Confirm that all the valves are closed and that the interlock switch is still “enabled.”

L.5.7 If S1 was not closed in L.5.4, wait until gyroscope has been delevitated (end of the spinup test) and then close S1.
L.6 Pre Spin-Up Checklist Gyro 2

Start Date: ______________________
Start Time: ______________________
Gyroscope #: ____________________

L.6.1 Verify the gyroscope is levitated and in the desired position

Record Position [X Y Z]: ______________________________

L.6.2 Verify that the gyroscope is not charged >70 volts

L.6.3 Verify that there is no oscillation in the position greater than 40 micro-inches.

L.6.4 Verify that the gyroscope has been levitated for at least one hour

L.6.5 Leakage Gas Pumping System is operating and the system Pressure < 5 x 10^{-5} torr

L.6.6 Spinup Exhaust Pumping System is operating and pressure is <5 x 10^{-3} torr (this is used to evacuate the spinup manifold)

L.6.7 Confirm manifold between the Probe C Gyro inlets (S1, S2, S3, or S4) and the Gyro Spinup management manifold (GSV-7) is connected, under vacuum, and has been certified according to P0567. Record Op. Log number:

L.6.8 Confirm the helium spinup gas supply is Grade 6 He and has Conformance Certification available.
L.7 Spinup Manifold Evacuation for Gyro 2

*Note: Refer to figure 1 for pumping system schematic.*

L.7.1 Check that SEP-1/SEP-2 pumps are operating and the pressure is $< 5 \times 10^{-3}$ torr. If the pumps are not running pressing the momentary switches on the right side of the schematic can start them. Place the system in Interlock Defeat mode and verify yellow LED is blinking.

L.7.2 Open auxiliary valves AXV-8, AXV-5, and the gas supply valve GSV-7. This will evacuate the spinup manifold up to the flow controller GSV-4. Confirm the Probe spinup valve is open. If it is not, gently open the Probe spinup inlet valve, S2. Close valves AXV-8, AXV-5, and GSV-7.

L.7.3 Turn off interlock defeat. The system is now ready to initiate Bypass flow.

L.8 Initiate Bypass flow for Gyro 2

L.8.1 Check to ensure the Spinup gas supply bottle has $> 250$psi. Open V5 and V6 at the helium supply bottle.

L.8.2 Open GSV-1 and GSV-2 (100 sccm flow controller).

L.8.3 Open GSV-6

L.8.4 Set GSV-4 mode switch to “auto” and rotate the 10-turn pot clockwise on GSV-2 until the desired flow is displayed on GSG-4. *Note: The numbers on the 10-turn pot dial will correspond with the output of the flow controller.* Start recording spin information in Table 2.

L.9 Gyroscope Spinup for Gyro 2

L.9.1 Start a FFT file on the Sun 386i. Record File name: ____________________

Record any additional useful information concerning the spin speed readout in the lines below (e.g. type of readout used, if the SQUIDs are being used, what range and gain are they on, etc.).

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L.9.2 When you are ready to start spinning the Gyroscope, open GSV-7.

L.9.3 Confirm GSV-6 closed while GSV-7 was opened.

L.9.4 Flow gas into the Spinup manifold. Monitor spin speed on the Sun 386i. Continue to record spin information in Table 2.

L.9.5 To stop spinup (either because the target spin speed has been reached, or to assess how the spinup is proceeding) open GSV-6 to reinitiate a bypass flow.

L.9.6 Steps L.9.1 – L.9.4 should be repeated as necessary to spin the gyroscope. Initially, use only a few sccm for a few seconds to get a feel for the spinup. This may be gradually increased as necessary. If it is uncertain whether or not the gyroscope is spinning after several attempts, stop the process and assess the situation.
<table>
<thead>
<tr>
<th>Time</th>
<th>Flow Rate (sccm)</th>
<th>Length of Flow</th>
<th>Gyro Spin Speed</th>
<th>Comments</th>
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</table>
L.10 Post-Spinup Procedure for Gyro 2

L.10.1 Turn the 10-turn pot counter clockwise until gas is no longer flowing. Display reads 000. Set the GSV-4 switch to “off”.

L.10.2 Close GSV-1 and GSV-2 to stop the flow of gas.
    Close GSV-6
    Open AXV-8 and AXV-5
    Turn on Interlock Defeat and Open GSV-7

L.10.3 Let the SEP pumps evacuate the manifold from the flow controller to the Gyroscope. This will evacuate some of the remaining He left in the spinup manifold.

L.10.4 (Optional) Gently close S2 on the Probe spinup inlet. Check if done: ________

L.10.5 Close GSV-7, AXV-5 and AXV-8

L.10.6 Confirm that all the valves are closed and that the interlock switch is still “enabled.”

L.10.7 If S2 was not closed in L.10.4, wait until gyroscope has been delevitated (end of the spinup test) and then close S2.
L.11 Pre Spin-Up Checklist Gyro 3

Start Date: ______________________

Start Time: ______________________

Gyroscope #: ____________________

L.11.1 Verify the gyroscope is levitated and in the desired position

Record Position [X Y Z]: ______________________________

L.11.2 Verify that the gyroscope is not charged >70 volts

L.11.3 Verify that there is no oscillation in the position greater than 40 micro-inches.

L.11.4 Verify that the gyroscope has been levitated for at least one hour

L.11.5 Leakage Gas Pumping System is operating and the system Pressure < 5 \times 10^{-5} \text{ torr}

L.11.6 Spinup Exhaust Pumping System is operating and pressure is <5 \times 10^{-3} \text{ torr}
   (this is used to evacuate the spinup manifold)

L.11.7 Confirm manifold between the Probe C Gyro inlets (S1, S2, S3, or S4) and the Gyro Spinup management manifold (GSV-7) is connected, under vacuum, and has been certified according to P0567. Record Op. Log number:

L.11.8 Confirm the helium spinup gas supply is Grade 6 He and has Conformance Certification available.
L.12 Spinup Manifold Evacuation for Gyro 3

Note: Refer to figure 1 for pumping system schematic.

L.12.1 Check that SEP-1/SEP-2 pumps are operating and the pressure is < 5 x 10^{-3} torr. If the pumps are not running pressing the momentary switches on the right side of the schematic can start them. Place the system in Interlock Defeat mode and verify yellow LED is blinking.

L.12.2 Open auxiliary valves AXV-8, AXV-5, and the gas supply valve GSV-7. This will evacuate the spinup manifold up to the flow controller GSV-4. Confirm the Probe spinup valve is open. If it is not, gently open the Probe spinup inlet valve, S3. Close valves AXV-8, AXV-5, and GSV-7.

L.12.3 Turn off interlock defeat. The system is now ready to initiate Bypass flow.

L.13 Initiate Bypass flow for Gyro 3

L.13.1 Check to ensure the Spinup gas supply bottle has > 250psi. Open V5 and V6 at the helium supply bottle.

L.13.2 Open GSV-1 and GSV-2 (100 sccm flow controller).

L.13.3 Open GSV-6

L.13.4 Set GSV-4 mode switch to “auto” and rotate the 10-turn pot clockwise on GSV-2 until the desired flow is displayed on GSG-4. Note: The numbers on the 10-turn pot dial will correspond with the output of the flow controller. Start recording spin information in Table 3.

L.14 Gyroscope Spinup for Gyro 3

L.14.1 Start a FFT file on the Sun 386i. Record File name: ____________________
Record any additional useful information concerning the spin speed readout in the lines below (e.g. type of readout used, if the SQUIDs are being used, what range and gain are they on, etc.).

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L.14.2 When you are ready to start spinning the Gyroscope, open GSV-7.

L.14.3 Confirm GSV-6 closed while GSV-7 was opened.

L.14.4 Flow gas into the Spinup manifold. Monitor spin speed on the Sun 386i. Continue to record spin information in Table 3.

L.14.5 To stop spinup (either because the target spin speed has been reached, or to assess how the spinup is proceeding) open GSV-6 to reinitiate a bypass flow.

L.14.6 Steps L.14.1 – L.14.4 should be repeated as necessary to spin the gyroscope. Initially, use only a few sccm for a few seconds to get a feel for the spinup. This may be gradually increased as necessary. If it is uncertain whether or not the gyroscope is spinning after several attempts, stop the process and assess the situation.
### Table 3-Gyro 3 Spinup

<table>
<thead>
<tr>
<th>Time</th>
<th>Flow Rate (sccm)</th>
<th>Length of Flow</th>
<th>Gyro Spin Speed</th>
<th>Comments</th>
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L.15 Post-Spinup Procedure for Gyro 3

L.15.1 Turn the 10-turn pot counter clockwise until gas is no longer flowing. Display reads 000. Set the GSV-4 switch to “off”.

L.15.2 Close GSV-1 and GSV-2 to stop the flow of gas.
   Close GSV-6
   Open AXV-8 and AXV-5
   Turn on Interlock Defeat and Open GSV-7

L.15.3 Let the SEP pumps evacuate the manifold from the flow controller to the Gyroscope. This will evacuate some of the remaining He left in the spinup manifold.

L.15.4 (Optional) Gently close S3 on the Probe spinup inlet. Check if done: ________

L.15.5 Close GSV-7, AXV-5 and AXV-8

L.15.6 Confirm that all the valves are closed and that the interlock switch is still “enabled.”

L.15.7 If S3 was not closed in L.15.4, wait until gyroscope has been delevitated (end of the spinup test) and then close S3.
L.16  Pre Spin-Up Checklist Gyro 4

Start Date: ______________________
Start Time: ______________________
Gyroscope #: ____________________

L.16.1 Verify the gyroscope is levitated and in the desired position
Record Position [X Y Z]: ______________________________

L.16.2 Verify that the gyroscope is not charged >70 volts

L.16.3 Verify that there is no oscillation in the position greater than 40 micro-inches.

L.16.4 Verify that the gyroscope has been levitated for at least one hour

L.16.5 Leakage Gas Pumping System is operating and the system Pressure < 5 x 10^{-5} torr

L.16.6 Spinup Exhaust Pumping System is operating and pressure is <5 x 10^{-3} torr
(this is used to evacuate the spinup manifold)

L.16.7 Confirm manifold between the Probe C Gyro inlets (S1, S2, S3, or S4) and the
Gyro Spinup management manifold (GSV-7) is connected, under vacuum,
and has been certified according to P0567. Record Op. Log number:

L.16.8 Confirm the helium spinup gas supply is Grade 6 He and has Conformance
Certification available.
L.17 Spinup Manifold Evacuation for Gyro 4

*Note:* Refer to figure 1 for pumping system schematic.

L.17.1 Check that SEP-1/SEP-2 pumps are operating and the pressure is $< 5 \times 10^{-3}$ torr. If the pumps are not running pressing the momentary switches on the right side of the schematic can start them. Place the system in Interlock Defeat mode and verify yellow LED is blinking.

L.17.2 Open auxiliary valves AXV-8, AXV-5, and the gas supply valve GSV-7. This will evacuate the spinup manifold up to the flow controller GSV-4. Confirm the Probe spinup valve is open. If it is not, gently open the Probe spinup inlet valve, S4. Close valves AXV-8, AXV-5, and GSV-7.

L.17.3 Turn off interlock defeat. The system is now ready to initiate Bypass flow.

L.18 Initiate Bypass flow for Gyro 4

L.18.1 Check to ensure the Spinup gas supply bottle has $> 250$psi. Open V5 and V6 at the helium supply bottle.

L.18.2 Open GSV-1 and GSV-2 (100 sccm flow controller).

L.18.3 Open GSV-6

L.18.4 Set GSV-4 mode switch to “auto” and rotate the 10-turn pot clockwise on GSV-2 until the desired flow is displayed on GSG-4. *Note: The numbers on the 10-turn pot dial will correspond with the output of the flow controller.* Start recording spin information in Table 4.

L.19 Gyroscope Spinup for Gyro 4

L.19.1 Start a FFT file on the Sun 386i. Record File name: ____________________

Record any additional useful information concerning the spin speed readout in the lines below (e.g. type of readout used, if the SQUIDs are being used, what range and gain are they on, etc.).

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________________________________________________________________________
L.19.2 When you are ready to start spinning the Gyroscope, open GSV-7.

L.19.3 Confirm GSV-6 closed while GSV-7 was opened.

L.19.4 Flow gas into the Spinup manifold. Monitor spin speed on the Sun 386i. Continue to record spin information in Table 4.

L.19.5 To stop spinup (either because the target spin speed has been reached, or to assess how the spinup is proceeding) open GSV-6 to reinitiate a bypass flow.

L.19.6 Steps L.19.1 – L.19.4 should be repeated as necessary to spin the gyroscope. Initially, use only a few sccm for a few seconds to get a feel for the spinup. This may be gradually increased as necessary. If it is uncertain whether or not the gyroscope is spinning after several attempts, stop the process and assess the situation.
### Table 4-Gyro 4 Spinup

<table>
<thead>
<tr>
<th>Time</th>
<th>Flow Rate (sccm)</th>
<th>Length of Flow</th>
<th>Gyro Spin Speed</th>
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L.20 Post–Spinup Procedure for Gyro 4

L.20.1 Turn the 10-turn pot counter clockwise until gas is no longer flowing. Display reads 000. Set the GSV-4 switch to “off”.

L.20.2 Close GSV-1 and GSV-2 to stop the flow of gas.
   Close GSV-6
   Open AXV-8 and AXV-5
   Turn on Interlock Defeat and Open GSV-7

L.20.3 Let the SEP pumps evacuate the manifold from the flow controller to the Gyroscope. This will evacuate some of the remaining He left in the spinup manifold.

L.20.4 (Optional) Gently close S4 on the Probe spinup inlet. Check if done: _______

L.20.5 Close GSV-7, AXV-5 and AXV-8

L.20.6 Confirm that all the valves are closed and that the interlock switch is still “enabled.”

L.20.7 If S4 was not closed in L.20.4, wait until gyroscope has been delevitated (end of the spinup test) and then close S4.
Figure 1: Gyro Gas Management System
Date/time: ______________
Operator's initials: __________
QA: __________

L.21 DATA SUMMARY (OPTIONAL):
L.21.1 Gyro #1 dF/dT ______________
L.21.2 Data file name and directory path: ____________________________
L.21.3 Gyro #2 dF/dT ______________
L.21.4 Data file name and directory path: ____________________________
L.21.5 Gyro #3 dF/dT ______________
L.21.6 Data file name and directory path: ____________________________
L.21.7 Gyro #4 dF/dT ______________
L.21.8 Data file name and directory path: ____________________________

L.21.9 Location of data analysis (lab book, matlab file, EM, etc.):
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

L.22 Spinup Valve Cycles Log
Note: Torque valves to 60 inch-lb.
S1 ______________
S2 ______________
S3 ______________
S4 ______________

Test completed. Completed by: __________________
Witnessed by: __________________
Date: ______________