GRAVITY PROBE B

PROCEDURE FOR

PAYLOAD VERIFICATION

P0519 REV B

GYRO FLOW AND THERMAL TESTING

07 July 2001

Prepared by: B. Clarke
Approvals:

Program Responsibility	Signature	Date
B. Clarke Gyro Verification		
R. Brumley Gyro RE		
M. Taber Payload Test Director		
D. Murray Cryogenic Engineer		
D. Ross GP-B Quality Assurance		
S. Buchman GP-B Hardware Manager		

NOTES:
Level of QA required during performance of this procedure:
___Stanford QA Representative
___Government QA Representative

All redlines must be approved by QA

Revision Record:

Rev	Rev Date	ECO #	Summary Description
A	04/09/01	1258	Update P-doc to include more precise traceability to requirements.
B	07/18/01	1284	Include provisions for controlling final filter heater with the flight ECU.

Acronyms and Abbreviations:

Acronym / Abbreviation	Meaning

Table of Contents

A Scope

This procedure will calibrate the leakage gas rate and investigate the thermal equilibrium temperature profile under fast spin flow conditions for the gyroscope under test.

B Requirements Verification

B.1 Requirements Cross Reference

Req't Source	Req't #	Requirement (Title and Description)	Achieved (Completed during Test)
3. PLSE-12	3.7.2.3.7	**Gas Leakage Into the Probe** - The rate of spin-up gas leakage from the gyroscope into the probe interior shall be as per 3.2.1.2.1.	
3. PLSE-12	3.2.1.2.1	**Vacuum During Spin-up -** The Science Payload shall be capable of maintaining a pressure of <= 7.1 x 10-2 Pa (5.3 x 10-4 torr) at the SIA during spin-up with a helium leakage mass flow rate <=110 micrograms/second through the probe. ***Note: 110 micrograms/second = 37.0 sccm (He-4) and 49.3 sccm (He-3)***	L3
3. PLSE-12	3.7.2.3.5	**Gas Temperature** – The temperature at the temperature sensor of the spin-up gas filter assembly at the inlet interface shall be adjustable over the range of 4-12 K and stable to +/- 0.25 K.	
3. PLSE-12	3.7.2.3.8	**Pressure at the SIA During Spin-up** - The pressure within the probe at the SIA shall be as per 3.2.1.2.1 for a gas leakage rate as per 3.2.1.2.1.	
3. PLSE-12	3.7.3.4.5.2	**Spin-up Inlet Line Filter Heating** - The probe shall provide heaters with the capability to warm the spinup inlet filter to >= 10 K.	
2. T003	12.9	**Spinup** - The probe supports a spinup system supplying each SG with low-temperature helium gas. Spinup gas leakage out of the channel shall be vented by a common line through the neck tube at a rate ensuring that the pressure between the SGs and the housing does not exceed 7.1 e-2 Pa (5.7 e-4 Torr). A gate valve on the front of the probe is opened during spinup to vent to space the residual gas leaking into the probe. During launch and measurement of Science Data the gate valve is closed.	
3. PLSE-12	3.7.2.3.4	**Gas Pressure** - The helium gas flow impedance of the probe and SIA shall be such that the spinup inlet gas pressure at the top hat interface shall not exceed 4.0 x 10^4 Pa (300 torr) for the spin-up gas flow rate specified in 3.2.1.7.1.	

B.2 Expected Data for verification per requirement

- Vacuum measurements made during the high flow test will verify PLSE-12 3.7.2.3.7, 3.2.1.2.1,3.7.2.3.8, and T003 12.9. These are the fundamental verifications that the probe/gyroscope system can support a high flow-rate spinup.
- GSG 4/5 will read the spinup inlet filter pressure during the flow test to support PLSE12 3.7.2.3.4. This requirement will be verified independently for each gyroscope.

- The Leakage Rate calibration (Section L3) verifies PLSE12 3.2.1.2.1. If the vacuum in the probe is better than 5.3 x 10^{-4} torr while flowing gas into the gyroscope at a flow rate of 37.0 sccm (He-4) or 49.3 sccm (He-3) with no exhaust, then the requirement is achieved. Note that if the ion gauge is calibrated for Nitrogen (as is customary) then it is necessary to apply a Gas Correction Factor (GCF) to correct for the difference in ionization potential. See Section L3.

C Configuration Requirements

Probe C is installed in the dewar and being pumped on by the Leakage Gas Management pumping system. The gyroscope under test is caged.

D Hardware Required

D.1 Flight hardware required

Description	No. Req'd
Probe C in Flight Dewar	1

D.2 Commercial test equipment

(Complete table per actual hardware used)

Manufacturer	Model	Serial Number	Calibr. Exp. Date
Flow Controller:			
Flow Readout:			
Ionization Gauge:			
Ion Gauge Readout:			

Gas Correction Factor used in Ion Gauge Calibration: _____ (1 = Nitrogren)

Pressure (He) = _____ x Pressure (Ion Gauge)

(insert correct Gas Correction Factor)

D.3 Mechanical/Electrical Special test equipment

Description	Part No.	Rev. no.	Serial No.	Certification Date
Probe C Leakage Gas Management System	N/A	N/A	N/A	N/A
Gyro spinup gas management system.	N/A	N/A	N/A	N/A
Facility Data Acquisition System	N/A	N/A	N/A	N/A
VAT Valve Controller	N/A	N/A	N/A	N/A

D.4 Tools

Description	No. Req'd

D.5 Expendables

Description	Quantity

E Software Required

No software is required.

F Procedures Required

No other procedures are required.

G Equipment Pretest Requirements

No equipment pretests required.

H Personnel Requirements

This test to be conducted only by the following certified personnel:

- Robert Brumley
- Chris Gray
- Bruce Clarke
- Larry Novak
- Ken Bower
- William Bencze
- Sasha Buchman

Only the following certified personnel may operate the Facility Data Acquisition System:

- Dave Murray
- Jim Maddocks
- Mike Taber

I Safety Requirements

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.

Electrostatic Discharge

Grounded wrist straps shall be worn at all times when mating to or demating from an electrical connector on Probe C.

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.

Mating and demating of flight hardware electrical connectors

- Connection and disconnection shall be performed only when the equipment involved is in a powered-down state.
- Connector savers are to be used unless otherwise specified.
- Connectors shall be inspected for contamination and for bent, damaged, or recessed pins prior to mating.
- Grounded wrist straps are to be worn prior to removal of connector caps or covers and during mating/demating operations.
- ESD-protective caps or covers are to be immediately installed after demating of connectors.
- Update all applicable mate/demate log when mating to or demating from any probe connector.

J General Instructions

- Redlines can be initiated by B. Clarke or R. Brumley and must be approved by QA.
- 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.
- Only the following persons have the authority to exit/terminate this test or perform a retest: Rob Brumley, Chris Gray, Ken Bower, Bruce Clarke, Sasha Buchman, and QA personnel

K References and Applicable Documents

Op. Order No._____

Date Initiated_____

Time Initiated_____

L OPERATIONS

NOTIFY ONR AND QA PRIOR TO THE START OF THIS PROCEDURE

L1 Pre-Test Checklist

Start Date: _____

Start Time: _____

Gyroscope # _____

Data acquisition and control of the final filter temperatures can be performed using either the GSE Facility Data Acquisition System (FDAS) or the flight Experimental Control Unit (ECU). In both cases it is permissible to use either a closed-loop control of the final filter temperature, or manually adjust the heater voltage until the desired gyroscope voltage is obtained (per the instructions in this procedure). Record the configuration used below:

Circle one: FDAS ECU

Circle one: Closed-Loop Control Open-Loop Control

L.1.1 Verify the gyroscope is delevitated.

L.1.2 Verify that the Leakage Gas Pumping System is operating and that the System Pressure (LGG-1A and LGG1B) < 5×10^{-6}. Both LGP-1 and LGP-2 should be pumping on the probe.

L.1.3 Verify that the Spinup Exhaust Pumping System is operating and that the Exhaust Gas Pressure (SEG-2) is $<5 \times 10^{-3}$.

L.1.4 Confirm that the manifold between the Probe C Gyro inlet (S1, S2, S3, or S4) and the Gyro Spinup Management Manifold (GSV-7, GSV-8, GSV-9 and GSV-10) is connected, under vacuum, and leak checked.

L.1.5 Confirm the manifold between the Probe C Gyro exhaust VAT valves (V1 & V2, or V3 & V4) and the Gyro Exhaust management manifold (SEV-2) is connected, under vacuum, and leak checked. (Note that only one pneumatic exhaust valve will be used – SEV-2. This valve will

serve two gyros that are plumbed in parallel, namely, GYRO #1 and GYRO #2 or GYRO #3 and GYRO #4).

L.1.6 Confirm that the helium spinup gas supply is Grade 6 He and has Conformance Certification available.

L2 <u>Evacuate Spinup and Exhaust Manifolds</u>

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

L.2.1 Check that SEP-1/SEP-2 pumps are operating and the SEG-2 is $< 5 \times 10^{-3}$. If the pumps are not running, pressing the momentary switches on the left side of the schematic will start them. Check that 'Interlock Defeat' is on.

L.2.2 Open auxiliary valves AXV-8, AXV-5 and the gas supply valve to the gyro under test (GSV-7→ Gyro #1, GSV-8 → Gyro #2, GSV-9 → Gyro #3 and GSV-10 → Gyro #4). This will evacuate the spinup manifold up to the flow controller GSV-4 and up to the probe spinup inlet valve.

L.2.3 The exhaust manifold should already be evacuated up to the Spinup Exhaust Valves (since manual valves GSV-11 and SEV-5 are normally left open. Check that the exhaust manifold is under vacuum by reading the pressure on gauges SEG-1 and SEG-2.

L.2.4 Open SEV-2. This will evacuate the exhaust manifold up to the exhaust VAT valve.

L.2.5 Open GSV-6 and close AXV-5 and AXV-8 (preparation for He gas flush).

L.2.6 ***Helium Flush of System.*** Now flush the system with He gas according to the times below. Flow rates of less than 100 sccm should be initiated using GSV-1 and GSV-2. Flow rates greater than 100 sccm should be initiated using GSV-1 and GSV-3.

75 sccm for at least 5 minutes
750 sccm for at least 5 minutes
75 sccm for at least 5 minutes
750 sccm for at least 15 minutes

NOTE: This step may be omitted if this procedure was performed on another gyroscope within 4 hours of performing this procedure. If so, indicate in the space below and list Op-Log Number of the relevant procedure.

_____

L.2.7 Reduce the flow to zero and close GSV-1, GSV-2, and GSV-3. Allow the system to pump out for several minutes before continuing.

L.2.8 Gently open the Probe spinup inlet valve for the gyro under test (S1 → Gyro #1, S2 → Gyro #2, S3 → Gyro #3 and S4 → Gyro #4).

L.2.9 Zero the Baritron gauges GSG-4, GSG-5 and SEG-1. Zero the flowmeters GSG-2 and GSG3.

L.2.10 Close the gas supply valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10). Close Spinup Exhaust Valve SEV-2 and auxiliary valves AXV-5 and AXV-8.

L.2.11 Check that the state of the valves is as follows: All pneumatic valves closed.

L3 <u>Calibrate the Leakage Rate</u>

L.3.1 Check that the spinup gas supply bottle contains > 250psi. Open V5 and V6 at the helium supply bottle.

L.3.2 Open GSV-1 and GSV-2 (100 sccm flow controller). Open gas supply bypass valve GSV-6.

L.3.3 If using the flight ECU, have a qualified operator initialize the ECU using an approved procedure. Have a qualified operator of either the Facility Data Acquisition System or the ECU (whichever is currently connected to the probe) start a log file and (if using the FDAS) a strip chart that includes:

Gyro temperature for each gyro	T01Q, T02Q, T03Q, T04Q
Final filter temperature for each gyro	T6P, T7P, T8P, T9P
Quartz block temperatures	T05Q, T06Q, T07Q, T10P, T11P, T17Q, T18Q
Heater power on final filter for the gyro under test	H1P, H2P, H3P or H4P

If hardware limitations restrict the number of temperatures that can be plotted on the strip chart, the RE and the Facility Data System Operator shall decide which of the above will be plotted on the strip chart. The strip chart time scale should be set such that a 15-minute interval will be easily discernible.

Record the data filename and path:

_____

Record any additional notes regarding the data acquisition or current setup:

L.3.4 Initiate a substantial bypass flow by rotating the 10-turn pot clockwise on GSV-4 until 80 sccm is displayed on GSG-2. Record the parameters in Table 1.

L.3.5 Turn the flow rate down to 10 sccm. Open the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10) then close the Bypass valve GSV-6. At the Re's discretion, when the probe pressure (indicated by PMG1-A/B and RGA) has reached equilibrium, record the parameters in Table 1.

L.3.6 Collect at least 2 more sets of values for different flow rates between 10 and 100 sccm, waiting for the probe pressure to equilibrate at each flow rate. Note that for He-4, 37.0 sccm is a mandatory data point and if using He-3 49.3 sccm is a mandatory stopping point. However, care must be taken when using He-3 as a flow controller calibrated for He-4 will not necessarily ready correctly for He-3. If the flow meter is not calibrated for He-3, then supply a supplementary data sheet appended to this procedure and signed off by the RE, the Payload Technical Manager, Systems Engineering, and QA which provides the necessary correction factor.

Requirements Verification:

If the RGA is functioning, use the He partial pressure indicated on the RGA. If not, then use the pressure indicated on PMG-1 A/B applying (if necessary) the gas correction factor listed in Section D.

Pressure used (circle one): RGA PMG-1

Pressure indicated: _____ torr

This pressure indicated completes the verification of PLSE-12 3.2.1.2.1. Fill in the number in the relevant row of the table in Section B. If the requirement is not met, then open a D-Log and consult with QA and the Payload Technical Manager (if the error is not shown to be GSE-related, then a DR will be necessary).

Requirement Achieved: Y N (circle one)

L.3.7 When the RE has determined that enough data has been collected, turn down the flow rate on GSV-4 to zero. Close GSV-2 and the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10).

L.3.8 Check that the state of the valves is as follows: All pneumatic valves closed except for GSV-1.

L.3.9 Append to this procedure (for future reference) a graph of the leakage rate data and the parameters for a linear fit of the input flow rate to probe pressure.

L4 Thermal and Flow Testing

L.4.1 Confirm the SEV-2 is closed. Open the exhaust VAT valve for the gyro under test. Open GSV-6 and GSV-3.

L.4.2 Initiate a high bypass flow by adjusting GSV-5 so that GSG-3 reads 800 sccm. Record the parameters in Table 2.

L.4.3 Reduce the flow rate to zero sccm. Close GSV-6. Open the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10).

L.4.4 Open Spinup Exhaust Valve SEV-2 and the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10). Increase the flow rate to 750 sccm stopping at 250 sccm and at 500 sccm to collect parameters in Table 2.

L.4.5 After a flow of 750 sccm is established, have the Facility Data Acquisition System operator or ECU operator ramp the final filter temperature. If it is not desired to thermal cycle the rotor, the input filter temperature shall not be increased to a level so that the gyro housing temperature exceeds 7.5 K. Wait for the filter temperature to ramp up and for the filter temperature, gyro temperature and the probe pressures to stabilize. Record the parameters in Table 2.

L.4.6 The target temperature for the gyro housing is between 6.5 and 7.0 K. The RE may select a new final filter target temperature and have the Facility Data Acquisition System operator or ECU operator ramp the filter temperature to this new temperature over 15 minutes or less in order to bring the gyro housing temperature into the desired range.

L.4.7 Step L.4.6 may be repeated as many times as the as the RE feels is necessary to assess the thermal characteristics of the filter heater/gyro/probe system under high flow conditions.

L.4.8 Check that the state of the valves is as follows: GSV-1, GSV-3, (GSV-7, GSV-8, GSV-9 or GSV-10), SEV-2 OPEN. All other pneumatic valves closed.

L.5 Post-Test Procedure

L.5.1 Once the RE has determined that enough data has been collected, have the Facility Data Acquisition System operator reduce the final filter heater power to zero. Continue to flow gas for 2 minutes. Record parameters in Table 2.

L.5.2 Turn the flow on GSV-5 down to zero. Close GSV-3, the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10) and SEV-2.

L.5.3 In order to isolate the probe from the spinup/exhaust manifold, close the exhaust VAT valve to gyro under test as well as the probe spinup supply valve (S1, S2, S3 or S4).

L.5.4 Confirm that all the valves are closed and that the interlock switch is “enabled”.

L.5.4 Have the Facility Data Acquisition System operator stop the strip chart and the data log. The strip chart will be attached to this procedure. The data log will be archived on the Payload Server.

Payload Server path and filename: _____.

L.6 Requirements Verification

3. PLSE-12	3.7.2.3.7	**Gas Leakage Into the Probe** - The rate of spin-up gas leakage from the gyroscope into the probe interior shall be as per 3.2.1.2.1.	

Record the He partial pressure observed at 750 sccm:

Pressure: _____ RGA Ion Gauge (with GCF incl) (circle 1)

Using the leakage rate calibration of L3, convert the pressure to a flow rate and record below

Equivalent flow rate: _____ sccm

If this flow rate is less than 37.0 sccm (for He-4) or 49.3 sccm (for He-3) then the requirement is met

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

3. PLSE-12	3.2.1.2.1	**Vacuum During Spin-up -** The Science Payload shall be capable of maintaining a pressure of <= 7.1 x 10-2 Pa (5.3 x 10-4 torr) at the SIA during spin-up with a helium leakage mass flow rate <=110 micrograms/second through the probe. ***Note: 110 micrograms/second = 37.0 sccm (He-4) and 49.3 sccm (He-3)***	ALREADY COMPLETED (See L3)

2. T003	12.9	**Spinup** - The probe supports a spinup system supplying each SG with low-temperature helium gas. Spinup gas leakage out of the channel shall be vented by a common line through the neck tube at a rate ensuring that the pressure between the SGs and the housing does not exceed 7.1 e-2 Pa (5.7 e-4 Torr). A gate valve on the front of the probe is opened during spinup to vent to space the residual gas leaking into the probe. During launch and measurement of Science Data the gate valve is closed.	

Record the He partial pressure observed at 750 sccm:

Pressure: _____ RGA Ion Gauge (with GCF incl) (circle 1)

If this pressure is less than 5.7 e-4, then the requirement is met.

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

3. PLSE-12	3.7.2.3.8	**Pressure at the SIA During Spin-up** - The pressure within the probe at the SIA shall be as per 3.2.1.2.1 for a gas leakage rate as per 3.2.1.2.1.	

Record the He partial pressure observed at 750 sccm:

Pressure: _____ RGA Ion Gauge (with GCF incl) (circle 1)

If this pressure is less than 5.7 e-4, then the requirement is met.

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

3. PLSE-12	3.7.3.4.5.2	**Spin-up Inlet Line Filter Heating** - The probe shall provide heaters with the capability to warm the spinup inlet filter to >= 10 K.	

Use the data obtained to calculate a inlet heater temperature / Input power. If necessary, append a page to this procedure to document the fit and calculation:

Fit = _____ K / W

Now record the power which the ECU can apply to these heaters: _____ W

Max Temperature = Fit x Max Power: _____ K (max temp)

If this is > 10 K, then the requirement is met.

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

Note: It may not be possible to take the spinup heater to > 10 K without exceeding the 7.5 K max temperature allowed at the gyro (to avoid a thermal cycle). This is why it is necessary to scale the requirement.

3. PLSE-12	3.7.2.3.5	**Gas Temperature** – The temperature at the temperature sensor of the spin-up gas filter assembly at the inlet interface shall be adjustable over the range of 4-12 K and stable to +/- 0.25 K.	

Use the data obtained to calculate a inlet heater temperature / Input power. If necessary, append a page to this procedure to document the fit and calculation:

Fit = _____ K / W

Now record the power which the ECU can apply to these heaters: _____ W

Max Temperature = Fit x Max Power: _____ K (max temp)

If this is > 12 K, then the requirement is met.

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

Provide a printout of the data file for the measured temperature to support the +/- 0.25 K stability requirement. Append this as a separate supplemental data sheet with any notations or calculations that are necessary to support the requirement (e.g. max T, min T).

This requirement can not be signed off as complete until the required data is supplied and reviewed by QA

Note: It may not be possible to take the spinup heater to > 12 K without exceeding the 7.5 K max temperature allowed at the gyro (to avoid a thermal cycle). This is why it is necessary to scale the requirement.

3. PLSE-12	3.7.2.3.4	**Gas Pressure** - The helium gas flow impedance of the probe and SIA shall be such that the spinup inlet gas pressure at the top hat interface shall not exceed 4.0 x 10^4 Pa (300 torr) for the spin-up gas flow rate specified in 3.2.1.7.1.	

Record the pressure on GSG4/5 during the 750 sccm flow test. If this is less than 300 torr, the requirement is passed.

Requirement Passed: Yes No (circle 1)

If no, enter D-Log # _____

Update the Table in Section B to reflect the results of this procedure as calculated in this section.

Test completed.

Completed by: _____

Witnessed by: _____

Date: _____

Time: _____

Table 1 – LEAKAGE RATE CALIBRATION

Time	Flow Rate (sccm	Pressure (torr)				
		PMG1-A/B	RGA (He)	LGG-1A/B	GSG-4/5	SEG-1
	10					
	37.0					
	49.3					

Table 2 – THERMAL FLOW DATA

Time	Flow Rate (sccm	Pressure (torr)					Temperature (K)		Power (mW)
		PMG1-A/B	RGA (He)	LGG-1A/B	GSG-4/5	SEG-1	Final Filter	Gyro Under Test	Filter Heater

Time	Flow Rate (sccm	Pressure (torr)					Temperature (K)		Power (mW)
		PMG1-A/B	RGA (He)	LGG-1A/B	GSG-4/5	SEG-1	Final Filter	Gyro Under Test	Filter Heater

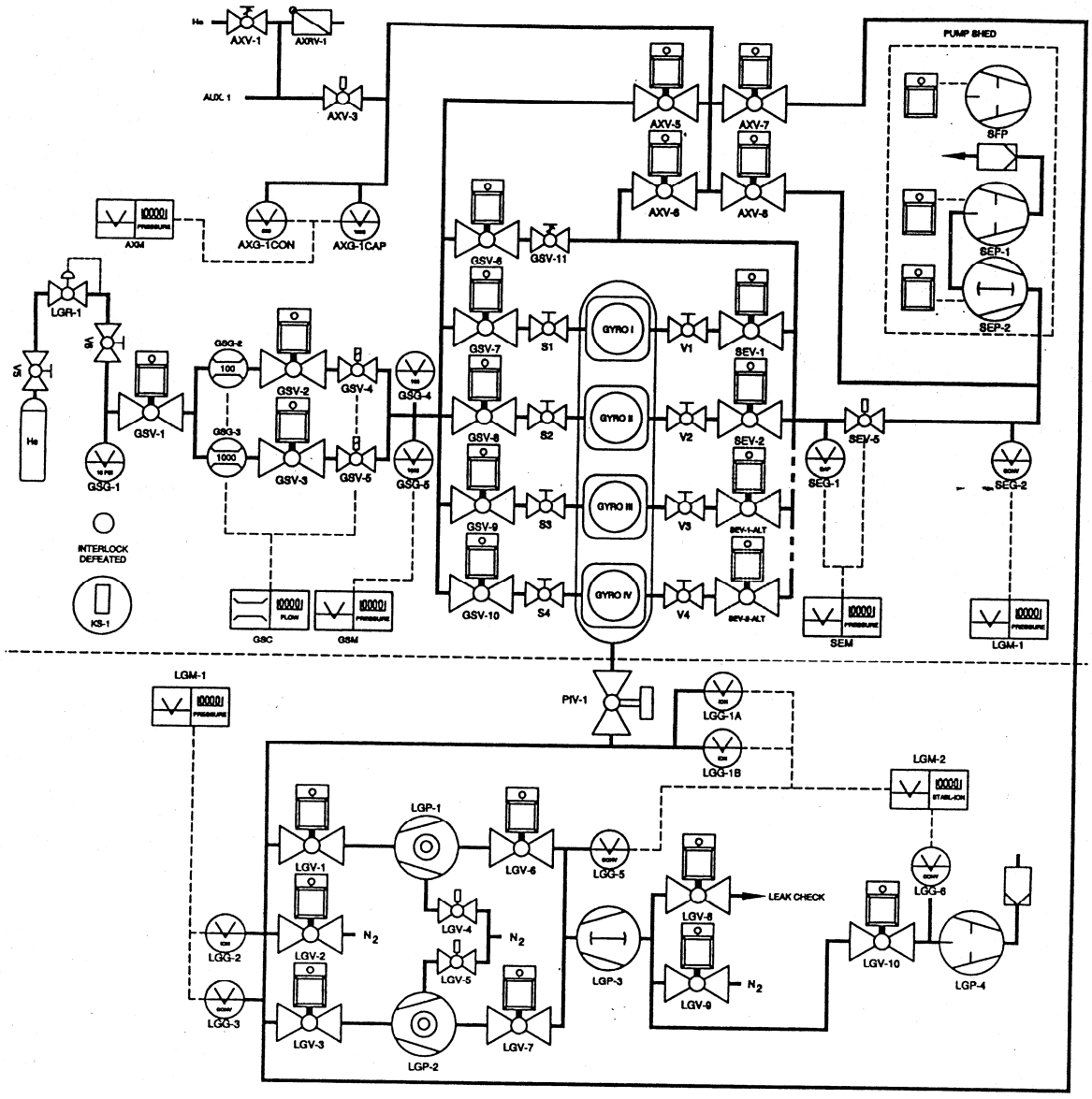

Figure 1: Gyro Gas Management System