Stanford University | **Gravity Probe B Program**
Procedure No. P0872 Rev. –
Operation Order No. _______

GRAVITY PROBE B

PROCEDURE FOR

PAYLOAD VERIFICATION

LOW TEMPERATURE BAKEOUT PRESSURE VERIFICATION

P0872 Rev.-
August 2, 2001

Prepared by: M. Taber

Approvals:

Program Responsibility	Signature	Date
M. Taber Cryogenics Manager		
D. Meriwether ECU Test Dir.		
R. Whelan Systems Eng.		
D. Ross GP-B Quality Assurance		
R. Brumley Payload Technical Manager		

NOTES:
Level of QA required during performance of this procedure:
_X_ Stanford QA Representative
___ Government QA Representative

All redlines must be approved by QA

Revision Record:

Rev	Rev Date	ECO #	Summary Description

Acronyms and Abbreviations:

Acronym / Abbreviation	Meaning
CEM	Channel Electron Multiplier
DAS	Data Acquisition System (for the SMD)
EM	Electron multiplier
FC	Faraday cup collector
GRT	Germanium Resistance Thermometer
GSE	Ground Support Equipment
IG	Ionization gauge
LD	Leak Detector
LGS	Leakage Gas System
NR	Not required, no revision
PPMS	Probe Pressure Measurement System
RGA	Residual Gas Analyzer
SMD	Science Mission Dewar
WTM	Wet Test Meter

Table of Contents

A Scope

This is a procedure to determine the ultimate vacuum that is reached as a result of performing “Low Temperature, Ultrahigh Vacuum Bakeout”, P0547. This involves the use of a Residual Gas Analyzer (RGA) as part of the Probe Pressure Measurement System (PPMS) to measure the helium partial pressure in the Probe. (All other gases measured at room temperature are irrelevant to the cryogenic region of the Probe.) Calibration of the RGA in the Faraday cup (FC) mode is accomplished by comparison to a calibrated Granville-Phillips Stabil-Ion ionization gauge at higher pressures (achieved by flowing helium gas through the Probe). This is followed by a cross-calibration from the FC mode to the electron-multiplier (EM) mode of the RGA at a lower pressure. In addition to the ultimate pressure, this procedure provides for a) recording the minimum pressure obtained before close-out and cool-down of the Probe, b) determination of the boil-off loss of liquid helium in the Main Tank due to bakeout, and c) measurement of the maximum temperature obtained at the top of the lead bag during bakeout.

B Requirements Verification and Success Criteria

B.1 Requirements Cross Reference: PLSE-12, 3.2.1.2.2 (and the derivative requirements 3.7.1.3.3.2, 3.7.3.5.3), and 3.7.3.5.2

B.2 Expected Data for verification per requirement:

B.2.1 Obtain <=10^{-11} torr after completion of bakeout (3.2.1.2.2, 3.7.1.3.3.2, 3.7.3.5.3).

B.2.2 Achieve a pressure of <= 10^{-7} torr after 12 hours of pumping before temperature reduction (3.7.3.5.2).

B.3 The success criteria is meeting the requirements as quoted above.

C Configuration Requirements

Integrated payload (probe + dewar) is operating with the main tank at 1.8 ±0.1 K. Gas flow from the exhaust of the pump that is pumping on the Main Tank is measured by a wet test meter with a shaft encoder connected to the DAS. Leakage Gas Pump System is running and connected to one 6” Vatterfly valve (LV1 or LV2). The exhaust valves V1, V2 are assumed to be connected to the Exhaust Gas Pump Manifold at SEV-1. The at least one of the probe gyro spinup inlet valves (S1-S4) is connected to one of the spinup supply valves (GSV-7, -8, -9 or -10) in order to supply helium to the probe for calibration. The ECU is connected to the Probe and SMD instrumentation connectors per P0547, and the SMD DAS is monitoring all the GRT thermometers at the top of the lead bag (T-20, 21, 22, 23D) and the silicon diode thermometer at the bottom of the Main Tank (T-9D).

C.1 General requirements:

D Hardware Required

D.1 Flight Hardware: Integrated payload (65113-1C34292-101), forward and aft ECU per P0547

D.2 Commercial test equipment:

Manufacturer / Descrip.	Model	Serial Number	Calibr. Exp. Date
Granville-Phillips ion gauge readout for "Stable-ion" ion gauges (PPG-1, -2) designated as LGM-1	360101	97071702 (LMCO cal ID # TRO 011769)	10/5/01

Manufacturer / Descrip.	Model	Serial Number	Calibr. Exp. Date
Granville-Phillips "Stable-ion" ion gauge (IG-1 = PPG-1)	360120	99012705 (LMCO cal ID # TRO 011769)	10/5/01
Granville-Phillips "Stable-ion" ion gauge (IG-2 = PPG-2)	360120	97071808 (LMCO cal ID # TRO 011769)	10/5/01
Leybold-Inficon RGA	H100M	6671-99	NR
Leybold-Inficon RGA electronics	Transpector 2.0	F8TT11B00155	NR
PC with TranspectorWare installed	As required for RGA software	-	NR

D.3 Mechanical/Electrical GSE and special test equipment: N/A

Description	Part No.	Rev. no.	Serial No.	Certification Date

D.4 Tools: N/A

Description	No. Req'd
Tape measure	1

D.5 Expendables: He spinup gas supply

E Software Required

E.1 Test Support Software: Leybold-Inficon TranspectorWare v. 2 or higher; DRP_SMD v. 250701 or higher for use with the DAS (P0547 requires additional software for ECU operation).

F Procedures Required

"Low Temperature, Ultrahigh Vacuum Bakeout", P0547, rev -

G Equipment Pretest Requirements: N/A

Equipment	Serial No.	Test Required	Proc. No.	Test Performed Date	By

H Personnel Requirements

This test to be conducted only by D. Meriwether (for P0547), M. Taber, and D. Murray. It is important that the conductor of this procedure be familiar with the operation of the RGA.

I Safety Requirements

I.1 Emergencies: In case of medical emergency or fire, **CALL 9-911**

I.2 Refer to FIST Emergency Procedures SU/GPB P0141 for other types of emergency situations which may occur in the FIST Lab. A copy of this document can be found in the SMD Operations binder. Refer also to the GP-B (FIST) Safety Plan, LMSC F-314447 and the GP-B

(FIST) Preliminary Hazards Analysis, LMSC F- 314446 for details concerning hazards and safe operation of Lockheed-supplied equipment.

I.3 Crane operations: The FIST Crane may be operated only by a certified operator.

J **General Instructions**

J.1 Redlines can be initiated by D. Meriwether (P0547), M. Taber, or D. Murray and must be reviewed and approved by QA.

J.2 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 Only the following persons have the authority to exit/terminate this test or perform a retest: D. Meriwether, M. Taber, or D. Murray.

K **References and Applicable Documents:** None

L **Operations**

Date:
Time:

L.1 Verify ONR / QA notification:

o Verify SU QA program office notified.

Record: Individual notified ___________________,

Date/time ________/________.

o Verify ONR representative notified.

Record: Individual notified ___________________,

Date/time ________/________.

L.2 Verify configuration:

L.2.1 Verify operation of the DAS in configuration 4w.

L.2.2 Record dewar temperatures: Date:___________

Time:___________

Thermometer	Location	Temperature (K)
T-9D [09]	Bottom, main tank	
T-15D [24]	Guard Tank	
T-20D {28}	Top of lead bag, (-x, +y)	
T-21D {29}	Top of lead bag, (+x, +y)	
T-22D {40}	Top of lead bag, (-x, -y)	
T-23D {41}	Top of lead bag, (+x, -y)	

L.2.3 Verify that the main tank temperature is 1.8 ±0.1 K.

L.2.4 Verify operation of the WTM, and record the current flow rate:______________slpm

L.2.5 Record main tank pumping configuration including EV–7a/b settings:
____.

CAUTION

In the following step, do NOT proceed to step K.3.6 of P0547, which opens LV2.

L.2.6 Perform P0547 (NR) through section K.3.5 to initialize the ECU and status the Vatterfly valves.

L.2.7 Record the QBS temperatures T-10P: ___________K, T-11P: ___________K. (Note: A complete set of probe temperatures is recorded in P0547.)

L.2.8 Verify that the Leakage Gas Pumping System is operating and that the System Pressure (LGG-1A or LGG-1B) <5 x 10 $^{-6}$. Both LGP-1 and LGP-2 should be pumping. Specify which LV is connected to the LGS and the status of the relevant LV: ____________________________________per Op. No.__________

L.2.9 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. Specify which gyro inlet valve S and supply valve GSV-____ are being used for this procedure.

L.2.10 Confirm the manifold between the Probe C Gyro exhaust VAT valves (V1 & V2, or V3 & V4) and the Gyro Exhaust management manifold (SEV-1) is connected, under vacuum, and leak checked. (Note that only one pneumatic exhaust valve will be used – SEV-1. This valve will serve two gyros that are plumbed in parallel, namely, GYRO #1 and GYRO #2 or GYRO #3 and GYRO #4).

L.3 If LV2 is to be used and it is not already open, perform K.3.6 through K.3.8 of P0547 to open LV2. Skip sections K.3.9 through K.3.11, which provide for opening LV1.

L.4 If LV1 is to be used and it is not already open, skip K.3.6 through K.3.8 of P0547, and perform K.3.9 through K.3.11 to open LV1.

L.5 Set up IG and RGA on the PPMS:

L.5.1 Obtain a copy of the current calibration information for LGM-1 and PPG-1 Stabil-Ion ionization gauge system and verify that the controller (LGM-1) is set to the correct emission current and sensitivity factor. Note that calibration of this gauge was done with N_2, and that according to the instruction manual for this gauge, the ionization probability of He is 0.18 compared to N_2. Thus, when He is being introduced, the increase in the He partial pressure is actually 5.56X the observed increase.

CAUTION:

The RGA being used has a channel electon multiplier (CEM) amplifier stage as well as a Faraday cup (FC) detector. The FC functions when the CEM high voltage is turned off. DO NOT OPERATE the CEM when the pressure is above 1 x 10^{-5} torr or when output currents in excess of 1 x 10^{-6} amps are obtained. Operation at excessive pressure or current may cause permanent damage. Also, use the minimum CEM voltage necessary to obtain a satisfactory signal. For this procedure, a CEM bias in excess of 1.0 kV will not be necessary. Excessive voltage will result in premature aging and loss of gain of the CEM.

L.5.2 Verify that the RGA on the PPMS is powered up and is connected to a serial port on a computer with TranspectorWare software installed.

L.5.3 Start up TranspectorWare and use the recipe editor to define a recipe using the Selected Peak mode (including H_2, He, H_2O, N_2, O_2, CO_2) with a cycle time of 15 sec. Specify the electron multiplier to be off at startup and to operate at a bias of 1.0 kV when turned on. Save this recipe as “bakefst.rcp”.

L.5.4 Define a second recipe the same as the first except that the cycle time should be 5 minutes. Save this recipe as “bakeslw.rcp”.

L.6 Evacuate Spinup and Exhaust Manifolds:

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

L.6.1 Verify that all AXV, GSV, SEV valves are closed.

L.6.2 Place system in “interlock defeat”

L.6.3 Check that SEP-1/SEP-2 pumps are operating and the SEG-2 is < 5 x 10^{-3}. If the pumps are not running, pressing the momentary switches on the right side of the schematic will start them.

L.6.4 Open auxiliary valves AXV-8, AXV-5 and the gas supply valve to the gyro being used for helium flow into the probe (the GSV specified in L.2.9). This will evacuate the spinup manifold up to the flow controller GSV-4 and up to the probe spinup inlet valve.

L.6.5 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.6.6 Open SEV-1. This will evacuate the exhaust manifold up to the exhaust VAT valve.

L.6.7 Open GSV-6 (this will close the GSV valve opened in L.6.4) and close AXV-5, AXV-8, and SEV-1 (preparation for He gas flush).

L.7 Helium Flush of System:

L.7.1 Verify that the spinup gas supply bottle contains > 250psi. Open V5 and V6 at the helium supply bottle.

L.7.2 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.

L.7.2.1 Flow 75 sccm for at least 5 minutes.

L.7.2.2 Flow 750 sccm for at least 5 minutes

L.7.2.3 Flow 75 sccm for at least 5 minutes

L.7.2.4 Flow 750 sccm for at least 5 minutes

L.7.3 Reduce the flow to zero and close GSV-2 and GSV-3. Briefly open AXV-8 and AXV-5 to allow the system to pump out for several minutes before continuing.

L.7.4 Zero the capacitance gauges GSG-4, GSG-5 and SEG-1. Zero the flowmeters GSG-2 and GSG-3.

L.7.5 Re-establish flow through GSV-2, -4, -6 at a rate of ~1 sccm.

L.7.6 Gently open the Probe spinup inlet valve (S valve) specified in L.2.9 and record in the Flight Valve Cycle Log.

L.8 Calibrate the RGA:

L.8.1 Verify that PPG-1 reads < 10^{-6} torr.

L.8.2 Start the RGA in the Monitor mode using the "bakefst" recipe. Record the path and filename of the data file:____.

L.8.3 Set the RGA data display in the "amps" mode.

L.8.4 Reread the caution in section L.5 regarding the use of the RGA.

L.8.5 Start recording data in Table 1. Also make use of the annotated mark feature of the RGA software whenever there is a change in conditions. Be sure to take the PPG-1 data at the same time the RGA data is taken if the He partial pressure is drifting.

L.8.5.1 Record data with the existing He partial pressure with the EM bias off.

L.8.5.2 Record data with the existing He partial pressure with the EM bias at 1 kV.

L.8.5.3 Record data with the existing He partial pressure with the EM bias off.

L.8.5.4 Open the GSV valve specified in L.2.9. This will establish a flow of ~1sccm He into the probe. When the pressures are reasonably stable, record in Table 1.

L.8.5.5 Increase the flow rate in small increments, taking data after the pressures are reasonably stable. Continue in this way until PPG-1 reaches an indicated pressure of 1 x 10^{-4} torr.

L.8.5.6 Open GSV-6 (closing the GSV valve to the gyro) and close GSV-1 and -2.

Table 1. RGA calibration data:

Date: ________ Time:	EM bias (kV)	GSG-2 flowrate (sccm)	RGA He ion current (A)	PPG-1 pressure (torr, N_2 equiv.)	LGG-1 pressure (torr, N_2 equiv.)	Comment
	0	0				
	1.0	0				
	0	0				

L.9 Secure spinup gas supply system:

L.9.1 Close and torque the Probe spinup inlet valve (S valve) specified in L.2.9 to 60 in-lbs and record in the Flight Valve Cycle Log.

L.9.2 Set the mode switches on the controllers for GSV-4 and GSV-5 to auto and turn up the set points until the red indicator lights come on.

L.9.3 Briefly open AXV-8 and AXV-5 to evacuate the spinup gas supply manifold.

L.9.4 Turn the set points on the flow controllers to zero and switch the mode switches to "off".

L.9.5 Close all open AXV, GSV, SEV valves and turn off SEP-1, -2.

L.10 Terminate the current RGA data file.

L.11 Prepare for bakeout:

L.11.1 Verify that AXV, GSV, SEV valves are closed and that SEP-1, -2 are off.

L.11.2 Open AXV-7, AXV-6, SEV-1 to pump up to V1 and V2 with the Leakage Gas Pump System.

CAUTION

In the following step, do NOT perform sections K.3.18 through K.3.23 of P0547, which open V3 and V4.

L.11.3 Perform sections K.3.12 through K.3.17 of P0547 to open the exhaust valves V1 and V2.

L.11.4 Restart the RGA software in the Monitor mode using the recipe "bakeslw". Set the readout units to "amps". Note: In the Monitor mode, it is possible to turn the EM bias on and off "on the fly".

L.11.5 Perform section K.4 (Open Loop Heater Checkout), and K.5 (Low Temperature Bakeout Initiialization) of P0547.

L.11.6 Make use of the annotation mark feature of the RGA software to note any significant events. Also manually record key data in Table 2.

L.12 Perform bakeout: Date: _____________
Time: _____________

L.12.1 Verify that the WTM is operating and that its data is being recorded by the DAS.

L.12.2 Record the current liquid helium boil-off rate as displayed by the DAS based on the WTM flowrate: __________mg/sec.

L.12.3 Make a comment in the DAS noting the beginning of low temperature bakeout.

L.12.4 Perform sections K.6 and K.7 of P0547. Continue to annotate the RGA data file and record data in Table 2. Be sure to record data in Table 2 after 12 hours of actual bakeout for verification purposes.

L.12.5 When the bakeout actually commences, record the current WTM gas totalization as follows:

L.12.5.1 Use [Other Menus], [Wet Test Setup], [WTM read] to obtain a real-time printoutof the WTM total.

L.12.5.2 Record the current WTM total: _________________ standard liters.

L.12.5.3 Return to the normal display by selecting [Exit].

L.12.6

L.12.7 When the He ion current signal starts to become noisy at the end of the bakeout or during cooldown, turn on the EM bias to obtain a more accurate result. It is preferable to do this for a couple of data cycles and then turn off the high voltage, rather than to leave the EM on continuously.

L.12.8 After closure of the Vatterfly valves, close QA:
DATE:
SEV-1 and AXV-6, -7. Verify that all AXV, SEV, and GSV valves are closed.

Table 2. Bakeout data

Date: ________ Time:	EM bias (kV)	RGA He ion current (A)	PPG-1 pressure (torr, N_2 equiv.)	LGG-1 pressure (torr, N_2 equiv.)	Comments

L.13 Complete bakeout: Date: _____________
Time: _____________

L.13.1 When the He partial pressure reaches its minimum value, record the final data in Table 2.

L.13.2 Terminate the RGA data file.

L.13.3 Enter a comment into the DAS that the bakeout has been completed.

L.13.4 Using the process described in L.12.4, obtain the current WTM gas totalization and record: _______________standard liters

M **Analysis**

M.1 Using the data in Table 1, calculate the 1 kV EM gain factor for He: ____________________

M.2 Enter the RGA He ion current (FC mode) and the PPG-1 pressure data pairs into a spreadsheet and plot. Discard non-linear data, if present, in the upper pressure range and perform a linear regression. Using the slope fit parameter (in amps/torr), multiply by the He ionization probability factor (0.18) to obtain the corrected value. Record the corrected RGA sensitivity value for He in the FC mode: _____________amps/torr (He). Attach a copy of the data plot and the linear fit.

M.3 Partial He pressure verification during bakeout:

M.3.1 Calculate the He partial pressure measured after 12 hours into the bakeout: ___________torr (at the PPMS)

M.3.2 To obtain the partial pressure at the SIA, correct the He partial pressure at the PPMS for thermal effusion by multiplying the by $(6/295)^{1/2} = 0.143$: _____________torr. This value should be <= 10^{-7} torr to verify the requirement of PLSE-12, section 3.7.3.5.2.

M.4 Partial He pressure verification after completion of bakeout:

M.4.1 Calculate the He partial pressure measured after completion of the bakeout: ___________torr (at the PPMS)

M.4.2 To obtain the partial pressure at the SIA, correct the He partial pressure at the PPMS for thermal effusion by multiplying the by $(3/295)^{1/2} = 0.101$: _____________torr. This value should be <=10^{-11} torr to verify the requirements of PLSE-12, sections 3.2.1.2.2, 3.7.1.3.3.2, 3.7.3.5.3.

Test completed.

Completed by: __________________
Date: __________________
Time: __________________

QA: __________________
Date: __________________

Cryo RE approval: ___________________
Date: ___________________

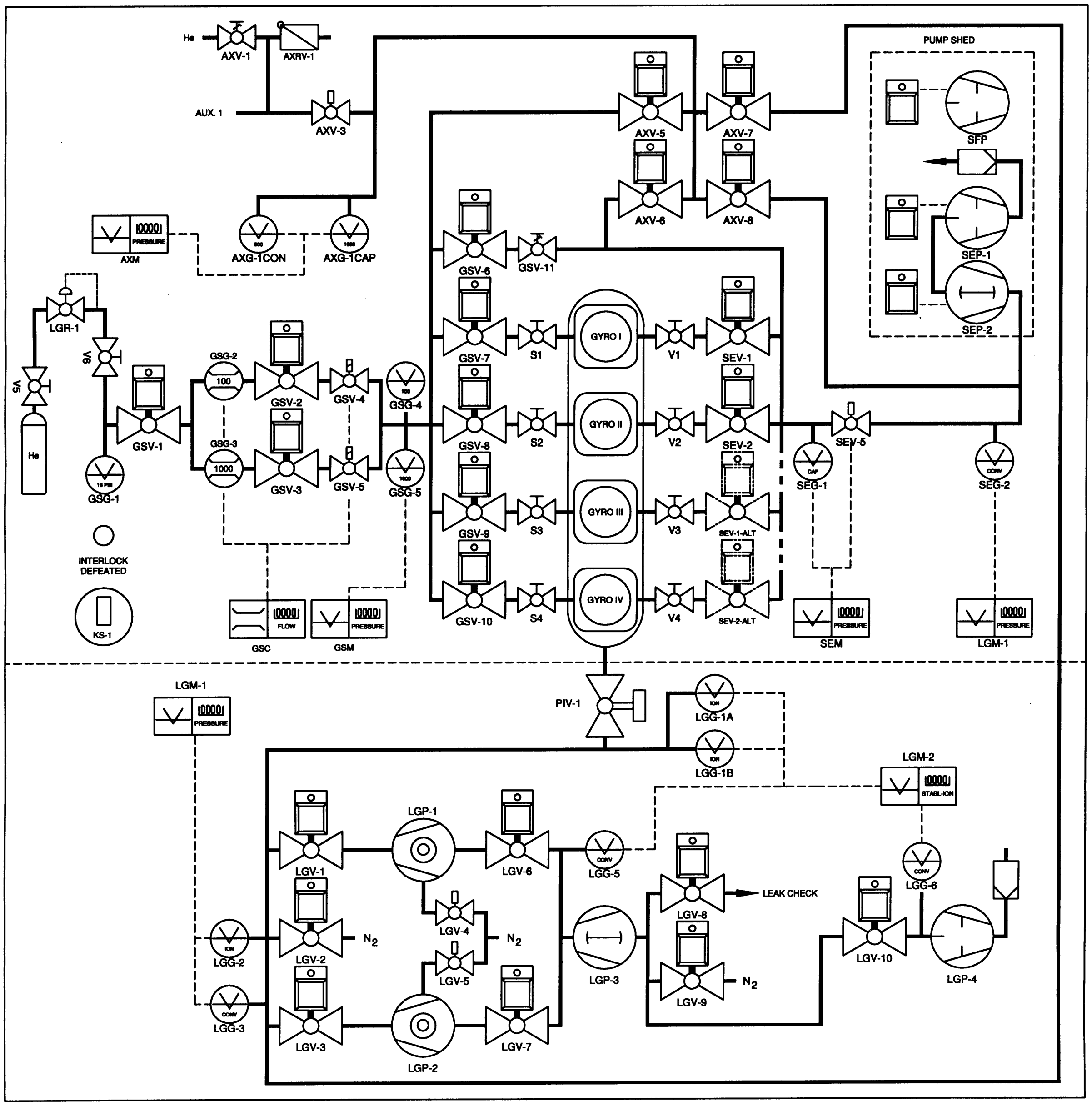

Fig. 1 Schematic diagram of the spinup GSE.