Operation No. _____

GRAVITY PROBE B
PROCEDURE FOR
SCIENCE MISSION DEWAR

REGULATE GUARD TANK PRESSURE

P0797 Rev-

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REVISION RECORD

REV	ECO	PAGES	DATE

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List of Abbreviations and Acronyms

AG-x	Gauge x of Gas Module auxiliary section
AMI	American Magnetics Inc.
AV-x	Valve x of Gas Module auxiliary section
CG-x	Gauge x of portable pressurization system
CV-x	Valve x of portable pressurization system
CPR-x	Pressure regulator x of portable pressurization system
CN [xx]	Data acquisition channel number
DAS	Data Acquisition System
EFM	Exhaust gas Flow Meter
EG-x	Gauge x of Gas Module exhaust section
EM	Electrical Module
ERV-x	Relief valve of Gas Module exhaust section
EV-x	Valve number x of Gas Module exhaust section
FCV	Fill Cap Valve
FIST	Full Integrated System Test
GHe	Gaseous Helium
GM	Gas Module
GP-B	Gravity Probe-B
GSE	Ground Support Equipment
GT	Guard Tank
GTVC	Guard Tank Vent Cap
GTVC-G	Guard Tank Vent Cap pressure gauge
GTVC-RV	Guard Tank Vent Cap relief valve
GTVC-V	Guard Tank Vent Cap valve
GTV-G	Guard Tank vent pressure gauge
GTV-RV	Guard Tank vent relief valve
GTV-V	Guard Tank vent valve
HX-x	Vent line heat exchanger in Gas Module
KFxx	Quick connect o-ring vacuum flange (xx mm diameter)
LHe	Liquid Helium
LHSD	Liquid Helium Supply Dewar
Liq	Liquid
LL	Liquid level
LLS	Liquid level sensor
LMMS	Lockheed Martin Missiles and Space
LMSC	Lockheed Missiles and Space Co.
MT	Main Tank
MTVC	Main Tank Vent Cap
MTVC-G	Main Tank Vent Cap pressure gauge
MTVC-RV	Main Tank Vent Cap relief valve
MTVC-V	Main Tank Vent Cap valve
NBP	Normal boiling point
ONR	Office of Naval Research
PFCG	Fill Cap assembly pressure Gauge
PFM	Pump equipment Flow Meter
PG-x	Gauge x of Pump equipment
PM	Pump Module
psi	pounds per square inch
psig	pounds per square inch gauge
PTD	Payload Test Director
PV-x	Valve x of the Pump equipment
QA	Quality Assurance
RAV-x	Remote Actuated Valve-x
RGA	Residual Gas Analyzer
SMD	Science Mission Dewar
STV	SMD Thruster vent Valve
SU	Stanford University
SV-x	SMD Valve number x
TG-x	Gauge x of Utility Turbo System
TV-x	Valve x of Utility Turbo System
UTS	Utility Turbo System
Vac	Vacuum
VCP-x	Vent cap pressure gauge
VCRV-x	Vent cap relief valve
VCV-x	Vent cap valve
VDC	Volts Direct Current
VF-x	Liquid helium Fill line valve
VG-x	Gauge x of Vacuum Module
VM	Vacuum Module
VV-x	Valve x of Vacuum Module
VW-x	Valve x of Dewar Adapter

A. SCOPE

This procedure describes the steps necessary to establish pressure regulation of the Guard Tank using an independent source of helium gas. The procedure may be accomplished when the Guard Tank vent line is connected to the Gas Module or disconnected, with a vent cap installed. The procedure involves disconnecting (when appropriate) one source of 99.99% pure helium gas and connecting another. It is intended primarily for the following uses:

1. The Guard Tank is empty with its pressure independently regulated and it is desired to change the regulation source (e.g., when preparing to move the SMD or when connecting the Guard Tank vent line to or disconnecting it from the Gas Module)
2. The Guard Tank contains a small amount of liquid (< 15%) and it is desired to establish pressure regulation as it runs dry.

Liquid in the Main Tank may be at NBP or subatmospheric and the Main Tank vent line may connected to the Gas Module or disconnected with a vent cap installed. The Well may be evacuated or contain liquid.

B. SAFETY

B.1. Potential Hazards

Personal injury and hardware damage can result during normal positioning, assembly and disassembly of hardware. Examples include: positioning Dewar in tilt stand; integrating probe with airlock; positioning airlock on Dewar; removing airlock from Dewar; removing probe from Dewar; and positioning support equipment such as pressurized gas cylinders and supply dewars.

A number of undesired events may be associated with these operations. For example, personnel or equipment can be struck when hardware is being moved (e.g. by forklift or crane load). Personnel are subject to entrapment while positioning hardware, such as hands or feet caught between objects as hardware is moved into place. Suspended hardware may be dropped. Personnel can be caught between objects such as forklifts and walls or loads and building support columns.

In addition, liquid helium used in the SMD represents a hazardous material for the personnel involved in the operations. Cryogenic burns can be caused by contact with the cold liquid or gas, high pressures can result if boiling liquid or cold gas is confined without a vent path, and asphyxiation can result if the vent gas is allowed to accumulate.

The SMD Safety Compliance Assessment, document GPB-100153C discusses the safety design, operating requirements and the hazard analysis of the SMD.

B.2. Mitigation of Hazards

B.2.1. Lifting hazards

There are no lifting operations in this procedure

B.2.2. Cryogenic Hazards

Helium gas venting from the SMD shall be vented through the facility exhaust duct. The facility has an oxygen deficiency monitor that alarms when the oxygen level is reduced to 19.5%. Additional temperature and pressure alarms, provided by the DAS, warn of potential over-pressure conditions. Emergency vent line deflectors are installed over the four burst disks on the SMD vacuum shell, and oxygen collection pans are on the floor beneath them.

The following requirements apply to personnel involved in cryogenic operations. Gloves that are impervious to liquid helium and liquid nitrogen are to be worn whenever the possibility of splashing or impingement of high-velocity cryogens exists or when handling equipment that has been cooled to cryogenic temperatures. Protective clothing and full-face shields are to be worn whenever the possibility of splashing cryogens exists.

The FIST Emergency Procedures document, SU/GP-B P0141, discusses emergency procedures. These documents should be reviewed for applicability at any facility where the hardware is operated.

B.2.3. Other Hazards

When appropriate, tools or other items used with the potential to damage the SMD or Probe shall be tethered. In addition, a foreign object and debris shield usually covers the upper cone of the SMD and is required whenever work is being performed above the SMD such that hard objects could fall and impact the apparatus.

B.3. Injuries

In case of any injury obtain medical treatment as follows
LMMS **Call 117**; Stanford University **Call 9-911**

C. QUALITY ASSURANCE

C.1. QA Notification

The ONR representative and SU QA shall be notified 24 hours prior to the start of this procedure. Upon completion of this procedure, the QE Manager will certify his/her concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating in the designated place(s) in this document.

C.2. Red-line Authority

Authority to red-line (make minor changes during execution) this procedure is given solely to the PTD or his designate and shall be approved by the QA Representative. Additionally, approval by the Hardware Manager shall be required, if in the judgement of the PTD or QA Representative, experiment functionality may be affected.

C.3. Discrepancies

A Quality Assurance Representative designated by D. Ross shall review any discrepancy noted during this procedure, and approve its disposition. Discrepancies will be recorded in a D-log or a DR per Quality Plan P0108. Any time a procedure calls for verification of a specific configuration and that configuration is not the current configuration, it represents a discrepancy of one of three types. These types are to be dealt with as described below.

1. If the discrepancy has minimal effect on procedure functionality (such as the state of a valve that is irrelevant to performance of the procedure) it shall be documented in the procedure, together with the resolution. Redlines to procedures are included in this category.
2. If the discrepancy is minor and affects procedure functionality but not flight hardware fit or function, it shall be recorded in the D-log. Resolution shall be in consultation with the PTD and approved by the QA representative.
3. All critical and major discrepancies, those that effect flight hardware fit or functions, shall be documented in a D-log and also in a Discrepancy Report, per P0108.

D. TEST PERSONNEL

D.1. Personnel Responsibilities

The performance of this procedure requires a minimum complement of personnel as determined by the Test Director. The Test Director is the designated signer for the “witnessed by” sign-off located at the end of each procedure. The person in charge of the operation (Test Director or Test Engineer) is to sign the “completed by” sign-off.

D.2. Personnel Qualifications

The Test Director must have a detailed understanding of all procedures and facility operations and experience in all of the SMD operations. Test Engineers must have SMD Cryogenic operations experience and an understanding of the operations and procedures used for the cryogenic servicing/maintenance of the Dewar.

D.3. Qualified Personnel

Test Director	***Test Engineer***
Mike Taber	Tom Welsh
Dave Murray	Chris Gray
Jim Maddocks	Bruce Clarke
Dave Frank	

E. REQUIREMENTS

E.1. Electrostatic Discharge Requirements

This procedure does not include any equipment sensitive to electrostatic discharge.

E.2. Lifting Operation Requirements

There are no lifting operations in this procedure

E.3. Hardware/Software Requirements

E.3.1. Commercial Test Equipment

No commercial test equipment is required for this operation.

E.3.2. Ground Support Equipment

The Ground Support Equipment includes the Gas Module, the Pump Module, the Electrical Module, and the Vacuum Module. The Gas Module provides the capability to configure vent paths, read pressures and flow rates, and pump and backfill vent lines. The Pump Module provides greater pumping capacity than the Gas Module, together with additional flow metering capabilities. The vent output of the Gas Module flows through the Pump Module. The Electrical Module contains the instruments listed in Table 1, and provides remote control of valves in the Gas Module, Pump Module, and SMD. The Vacuum Module contains a turbo pump, backed by a vane pump, and provides the capability to pump out the SMD vacuum shell.

This procedure calls for use of hardware located in the Gas Module (Figure 1), the Electrical Module (Table 1), and the Portable Helium Gas Pressurization System (Figure 4). Specifically, the regulator APR-2 serves to regulate the Guard Tank pressure through EV-23 and GTV-V when the Guard Tank vent line is connected to the Gas Module, and APR-3 regulates the pressure through APR-3V and GTV-Va when the Guard Tank vent line is disconnected from the Gas Module. When it is necessary to transport the entire SMD, making use of the Gas Module impossible, regulator CPR-1 on the Portable Helium Gas Pressurization System controls the pressure through CV-2 and GTV-Va.

E.3.3. Computers and Software:

The Data Acquisition System (DAS) and data acquisition software are required for this procedure. The DAS reads and displays pressures, temperatures, and flow rates and monitors critical parameters. No additional computers or software are required.

E.3.4. Additional Test Equipment

E.3.5.

Description
Endevco pressure transducer readout, model 136

E.3.6. Additional Hardware

No additional hardware is required.

E.3.7. Tools

No tools are required for this operation.

E.3.8. Expendables

Description

Source of 99.99 % pure helium gas.

E.4. Instrument Pretest Requirements

N/A

E.5. Configuration Requirements

E.5.1. Main Tank
Liquid in the Main Tank may be subatmospheric or at its normal boiling point (NBP)

E.5.2. Guard Tank
The Guard Tank must contain liquid < 15% liquid level or be depleted with its pressure independently regulated.

E.5.3. Well
The Well may contain liquid or be evacuated.

E.5.4. SMD Vacuum Shell
When the Guard Tank contains liquid, the Vacuum Shell pressure must be less than 1 x 10-5 torr and have been pumped within the last month. Document No. P0213 contains the procedure for connecting to and pumping on the SMD vacuum shell.

E.5.5. Alarm System

1. The DAS alarm system must be enabled and contain the following alarm set-points:
   a. Station 200 temperature (CN [01]) set at $T \leq 6.5$ K.
   b. Top of lead bag temperature set (CN [28]) at $T \leq 6.0$ K.
   c. Relative Guard Tank Pressure (CN [46]) set at $\Delta P \geq 0.3$ torr.
2. The Facility Main Alarm System must be armed.

E.5.6. GSE and Non-flight Hardware

1. The ion-pump magnet is installed.
2. GSE cabling must be connected between the SMD and the Electrical Module (P/N 5833812) and between the SMD and the Data Acquisition System (P/N 5833811).

E.6. Optional Non-flight Configurations

The following modifications or non-flight arrangement of the basic SMD configuration may also be in place. They are incidental to the performance of this procedure and not required.

1. The SMD is installed in its transportation and test fixture, or it may be installed in the tilt dolly or other transportation fixture.
2. A foreign object and debris shield may cover the upper cone of the SMD.
3. A relief valve may be installed in place of the SMD fill-line burst disk.
4. The Main Tank vent line may be connected to the Gas Module or it may be disconnected with a vent cap installed.
5. The Guard Tank vent line may be connected to the Gas Module or it may be disconnected with a vent cap installed.

6. The Fill Cap Assembly may be installed at SV-13 (See Figure 2)
7. The Airlock Support Plate may be installed on the SMD. This plate supports the Airlock that is used to keep air out of the Well during probe installation and removal. It is left in place while the Probe is removed.
8. A Dewar Adapter, Shutter, and Shutter Cover are mounted to the Well of the SMD when the Probe is removed
9. The Well often contains liquid. When it does, it vents through the Gas Module unless Well operations are being performed (e.g., Probe insertion). Venting through the Gas module is accomplished via a pumping line attached to the Dewar Adapter interface flange at the Airlock Support Plate (Probe not installed), or via a pumping line attached to the Well vent manifold installed at the Well pump-out port (Probe installed). When performing Well operations, the Well vents to the room
10. The Vacuum shell pump out port at SV-14 may be connected to the Vacuum Module (P/N 5833816) via a 2-in valve operator and pumping line, with the valve in either the closed position or in the open position. The Vacuum Module pump may be; off, actively pumping the pumping line up to a closed SV-14, or actively pumping the vacuum shell.
11. The thruster vent port may be flanged to a shut-off valve.

F. REFERENCE DOCUMENTS

F.1. Drawings

Drawing No.	***Title***
LMMS-5833394	*Instrumentation Installation*

F.2. Supporting documentation

Document No.	***Title***
LMMC-5835031	*GP-B Magnetic Control Plan*
GPB-100153C	*SMD Safety Compliance Assessment*
SU/GP-B P0141	*FIST Emergency Procedures*
LMSC-P088357	*Science Mission Dewar Critical Design Review*
SU/GP-B P0108	*Quality Plan*
LMMS GPB-100333	*Science Mission Dewar Failure Effects and Causes Analysis*
SU/GP-B P059	*GP-B Contamination Control Plan*

F.3. Additional Procedures

Document No.	***Title***
SU/GP-B P0213	Connect Vacuum Module / Pump on SMD Vacuum Shell

Operation Number:_____

Date Initiated:_____

Time Initiated:_____

G. OPERATIONS

G.1. Verify Appropriate QA Notification

- o Verify SU QA notified.

  Record: Individual notified _____,

  Date/time _____/_____.

- o Verify ONR representative notified.

  Record: Individual notified _____,

  Date/time _____/_____.

G.2. Verify Configuration Requirements

G.2.1. Ensure Facility Main Alarm System enabled.

G.2.2. Verify proper sealing of Well. Record closure (cover plate, Hole cutter, Probe etc.)._____.

G.2.3. Record location of SMD (FIST test fixture, tilt dolly, etc.) _____.

_____.

G.2.4. Ensure DAS or TM&A alarm system enabled and record set points.

1. ***Station 200 temperature*** – ensure CN [01] on alarm list and set to alarm at $T \leq 6.5$ K. Record set point. _____K
2. ***Top of lead bag temperature*** – ensure CN [28] on alarm list and set to alarm at $T \leq 6.0$ K. Record set point. _____K
3. ***Relative Guard Tank pressure*** – ensure CN [46] on DAS alarm list and set to alarm at $\Delta P \geq 0.3$ torr. Record set point. _____torr

G.3. Record Initial Conditions

G.3.1. Record Guard Tank configuration (check all that apply)

- o Guard Tank contains liquid and is not currently pressure regulated.
- o Guard Tank contains liquid and is pressure regulated.
- o Guard Tank is empty and is pressure regulated.
- o Guard Tank vent line connected to Gas Module
- o Guard Tank vent line disconnected.

G.3.2. Record Guard Tank temperature CN [24] _____ K.

G.3.3. Record Guard Tank pressure (GTV-G) _____ torr diff.

G.3.4. Record liquid helium levels, as applicable:

1. Main Tank level (LL-1D or LL-2D) _____%
2. Well level (LL-3LD or LL-4D) _____%
3. Guard Tank level (LL-5D or LL-6D) _____%
4. Axial Lock level (LL-7D or LL-8D) _____%

G.3.5. Record Main Tank configuration (check all that apply)

- o Main Tank vent line connected to Gas Module
- o Main Tank vent line disconnected.
- o Main Tank at NBP.
- o Main Tank subatmospheric.

G.4. (Option) Regulate Pressure Allowing Guard Tank to Deplete

CAUTION
Be aware that if the Guard Tank is emptied while the Main Tank is subatmospheric, it will be necessary to warm the Main Tank to NBP before the Guard Tank can be refilled.

- o Guard Tank pressure is already independently regulated – skip this section and proceed to next section.
- o Guard Tank pressure is not independently regulated – complete this section.

G.4.1. Ensure ion-pump magnet installed.

G.4.2. Ensure Vacuum Shell Pressure < 5 x 10^{-5} torr.

1. Turn on Vac-ion pump and record time of day _____
2. Use DAS [Monitor Data] CN [99] to monitor ion pump pressure.
3. When value is steady, record pressure (IP) _____ torr.
4. If pressure is above 5x10^{-5} torr, turn off Vac-ion pump and perform procedure P0213 to pump out SMD vacuum shell with Vacuum Module. Record operation number _____.
5. Exit [Monitor Data] and collect data with [Set Data Interval] to existing interval.
6. When data cycle is complete, turn off Vac-ion pump.

G.4.3. Verify Guard Tank contains < 15% liquid. Record level ____ %.

G.4.4. Verify GTV-V open.

G.4.5. Indicate source of regulation and proceed as indicated.

- Regulate GT pressure with APR-3 through GTV-Va.
  1. Verify closed/close GTV-Va.
  2. Connect/verify connected source of helium gas to APR-3.
  3. Close GTV-V and record time _____ hrs.
  4. Input comment to DAS: “Close GTV-V.”
  5. Monitor Guard Tank pressure GTV-G until it is 50 torr greater than atmospheric pressure then proceed as follows.
  6. Disconnect pressurization line from GTV-Va if present.
  7. Close/verify closed APR-3V.
  8. Set pressure at APR-3 to regulate at 2.5 to 3 psig.
  9. Open APR-3V and purge pressurization line for 1 minute.
  10. Open GTV-Va slightly and connect pressurization line while purging.
  11. Close GTV-Va and record time of day _____ hrs.
  12. When 4.5 psig relief valves start relieving open GTV-Va.
  13. Record time of day _____ hrs.

- Regulate GT pressure with APR-2 through EV-23.
  1. Verify closed/close EV-23, EV-24, and GTV-Va.
  2. Verify source of helium gas connected to APR-2 ____ yes ____ no.
  3. Close/verify closed EV-13 and EV-20 and record time _____ hrs
  4. Enter comment to DAS “Close EV-13 and EV-20.”
  5. Monitor Guard Tank pressure GTV-G until it is 50 torr greater than atmospheric pressure and proceed.
  6. If helium source not already connected to APR-2 (step 2), purge pressurization line as follows:
     a. Connect helium gas source to APR-2
     b. Set pressure at APR-2 to regulate at 2.5 to 3 psig
     c. disconnect pressurization line from upstream side of EV-23
     d. Purge line for 1 minute
     e. Open EV-23 slightly and reconnect pressurization line to EV-23 while purging.
     f. Close EV-23 and record time of day _____ hrs.
  7. When relief valves in Gas Module begin relieving, Open EV-23.

8. Record time of day _____ hrs.

- Regulate GT pressure with Auxiliary Helium Pressurization System (CPR-1) through GTV-Va.
  1. Verify closed/close GTV-Va.
  2. Connect/verify connected source of helium gas to CPR-1.
  3. Close GTV-V and record time _____ hrs.
  4. Input comment to DAS: “Close GTV-V.”
  5. Monitor Guard Tank pressure GTV-G until it is 50 torr greater than atmospheric pressure then proceed as follows.
  6. Disconnect pressurization line from GTV-Va if present.
  7. Open/verify open CV-1.
  8. Close/verify closed CV-2.
  9. Set pressure at CPR-1 to regulate at 2.5 to 3 psig.
  10. Open CV-2 and purge pressurization line for 1 minute.
  11. Open GTV-Va slightly and connect pressurization line while purging.
  12. Close GTV-Va and record time of day _____ hrs.
  13. When 4.5 psig relief valves start relieving open GTV-Va.
  14. Record time of day _____ hrs.

G.5. (Option) Change Guard Tank Pressurization Source

- It is not desired to change the Guard Tank source of pressure regulation – skip this section and proceed to the next section.
- Guard Tank pressure is independently regulated and it is desired to change the source of regulation– complete this section.

G.5.1. Guard Tank pressure is currently controlled by:

- APR-2 through EV-23
- APR-3 through APR-3V and GTV-Va
- CPR-1 through CV-2 and GTV-Va

G.5.2. Record pressurization set point _____ psig.

G.5.3. Set up new source of pressure control

- Regulate using APR-2 through EV-23 (GT vent connected to GM).
  1. Verify closed/close EV-13, EV-20, EV-23 and EV-24.
  2. Verify source of helium gas connected to APR-2 ____ yes ____ no.
  3. If helium source already connected to APR-2:
     a. Set pressure at APR-2 to regulate at set point recorded in G.5.2.
     b. Open EV-23.
  4. If helium source not already connected to APR-2, purge pressurization line as follows:
     a. Connect helium gas source to APR-2
     b. Set pressure at APR-2 to regulate at 2.5 to 3 psig
     c. disconnect pressurization line from upstream side of EV-23
     d. Purge line for 1 minute
     e. Open EV-23 slightly and reconnect pressurization line to EV-23 while purging
     f. Open EV-23 fully.
  5. Close GTV-Va.
  6. Close APR-3V or CV-2 as appropriate.

- Regulate with APR-3 through APR-3V and GTV-Va (GT vent disconnected or to be disconnected from GM)
  1. Connect/verify connected source of helium gas to APR-3.
  2. Close/verify closed APR-3V.
  3. Set pressure at APR-3 to regulate at set point recorded in G.5.2.
  4. Open APR-3V and purge new pressurization line for 1 minute.
  5. Close/verify closed GTV-V and GTV-Va
  6. Disconnect old pressurization line from GTV-Va if present.
  7. Open GTV-Va slightly and connect new pressurization line while purging.
  8. Open GTV-Va fully.
  9. Close EV-23 or CV-2 as appropriate.

- Regulate with CPR-1 through CV-2 and GTV-Va.
  1. Close/verify closed CV-2.
  2. Open CV-1
  3. Verify availability of helium gas.
     Record pressure CG-1 _____ psig.
  4. Set CPR-2 to regulate at set point recorded in G.5.2.
  5. Open CV-2 and purge new pressurization line for 1 minute.
  6. Close/verify closed GTV-V and GTV-Va
  7. Disconnect old pressurization line from GTV-Va if present.
  8. Open GTV-Va slightly and connect new pressurization line while purging.
  9. Open GTV-Va fully.
  10. Close EV-23 or APR-3V as appropriate.

G.6. Verify Final Configuration

G.6.1. Ensure that power to Vac-Ion pump is off.

G.6.2. Ensure DAS or TM&A alarm enabled and record set points if changed

- Thermal conditions substantially unchanged, alarm set points for Station 200 and lead bag unchanged
- Thermal conditions substantially changed, temperature alarm points reset as follows:
  a. Station 200 set point [CN 1] _____ K (≤ 6.5 K)
  b. Top of Lead Bag set point [CN 28] _____ K (≤ 6.0 K)

G.6.3. Ensure Guard Tank pressure on DAS or TM&A alarm list and set to alarm at 0.3 torr differential.

G.6.4. Ensure Facility Main Alarm System enabled.

Completed by:_____

Witnessed by:_____

Date: _____

Time:_____

Quality Manager_____**Date**_____

Payload Test Director_____**Date**_____

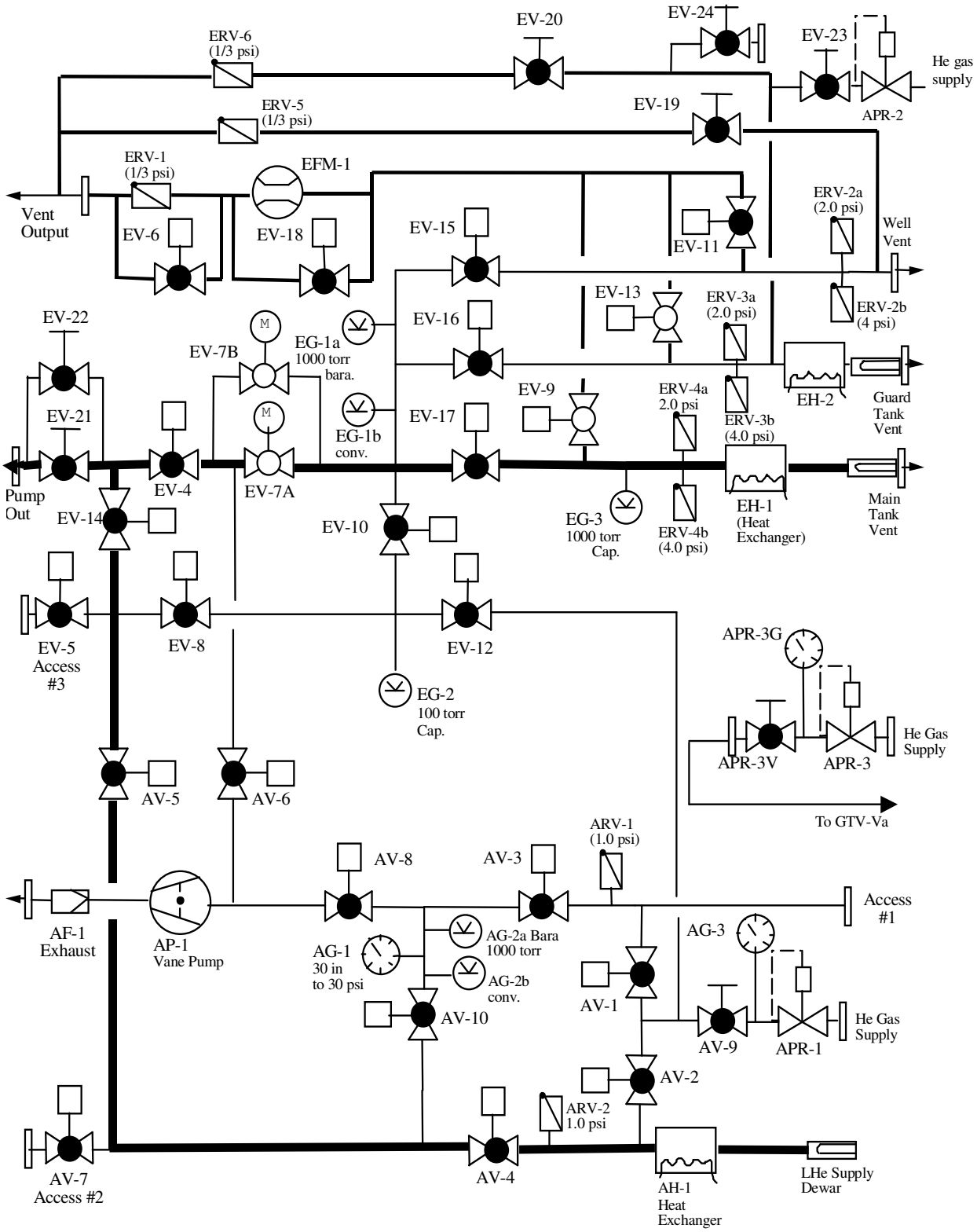

Figure 1. Schematic of Gas Module Plumbing.

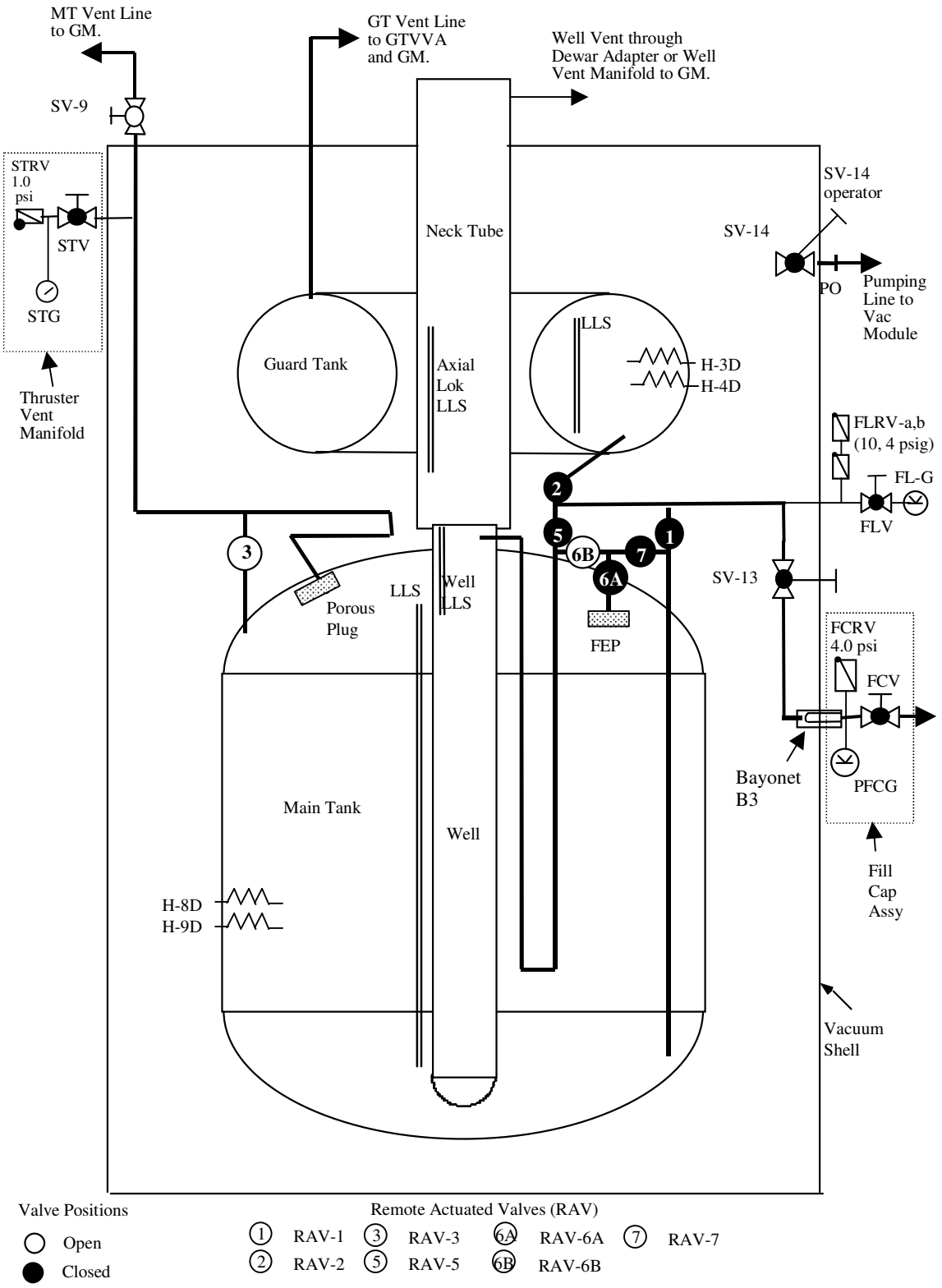

Figure 2. Schematic of Science Mission Dewar plumbing.

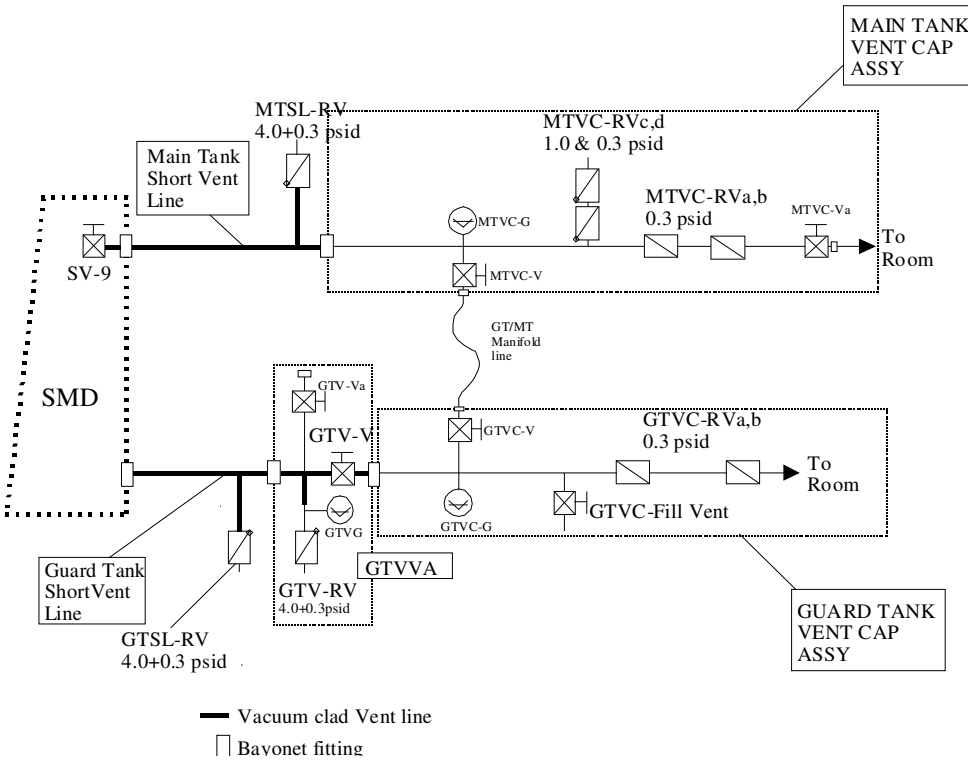

Figure 3. Schematic representation of Guard Tank Vent Valve Assembly and Main Tank and Guard Tank vent cap assemblies.

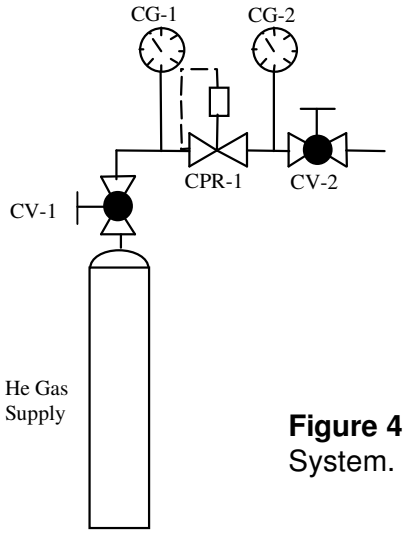

Figure 4 Portable Helium Gas Pressurization System.